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ABSTRACT

Trained personnel will be needed in the future to install solar energy heating and hot water systems, and public school vocational education teachers will be needed to train these technicians. A project to train high school vocational teachers so that they can teach their students about solar energy concepts, manufacturing techniques, testing, and installation was conducted by the Talcott Mountain Science Center in Connecticut. During the second year of the program, the number of participants was increased from 15 to 25; an instructional resource guide to be used as a curriculum infusion unit by vocational education teachers was prepared; selected participants of the first-year course were drawn into the teaching scheme; lectures and laboratory sessions were carried out in the schools represented by participants; field experience was provided by installing two solar systems at Talcott Mountain; and a means was established for teachers to use the program for graduate credit for continuing professional education. It was found that more than half of the first-year participants were teaching energy courses in their high schools; and it was hoped that the increased reliance on hands-on solar installation experience in the second-year program would lead to further use of skills learned and materials prepared. It was recommended that additional courses be set up in three 10-to-15-week models dealing with (1) skills needed on the job; (2) curriculum and engineering theories needed for the classroom; and (3) actual installations at several sites. (Learning activities are included in the report.) (KC)

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MODEL SOLAR ENERGY TRAINING PROGRAM II

FINAL REPORT

PREPARED BY:

TALCOTT MOUNTAIN SCIENCE CENTER FOR STUDENT INVOLVEMENT, INC.

MONTEVIDEO ROAD - AVON, CONNECTICUT

PREPARED FOR:

CONNECTICUT STATE DEPARTMENT OF EDUCATION

DIVISION OF VOCATIONAL EDUCATION

BUREAU OF VOCATIONAL PROGRAM PLANNING & DEVELOPMENT

HARTFORD, CONNECTICUT 06115

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ACKNOWLEDGEMENTS

We would like to thank those individuals of the Bureau of Vocational Program Planning and Development (BVPPD) for funding a truly important project for the second year. The guidelines, intent, and operation of this project, and others funded through the same program, have been discussed at awareness meetings conducted by the Bureau. At these sessions, participants were encouraged to ask questions in an atmosphere of free exchange which benefited all present.

We are also grateful for the on-site visits to the Project made by Bureau personnel. The opportunities to display what we are all about, and to discuss our approaches and techniques was of great benefit to us.

In particular, we acknowledge the help and guidance of Dr. Elizabeth Schmitt, Chief of BVPPD, and Dr. Valerie Pichanick, Consultant, BVPPD. We would also wish to thank Mr. Edward Shia, from the Bureau of Vocational Services, Mr. Edward Butler, from Sunrise Solar, Mr. Philip Fine, Vice President of Energy Research Group, and Mr. Edward Morris, from H.C. Wilcox Regional Technical School for serving on the advisory committee of the project. Their cooperation in reviewing course materials, documenting the course syllabus, and making suggestions on the final curriculum materials has greatly enhanced this project.

PREFACE

> "One institutional barrier (to effective use of solar energy systems) is lack of skills in installing and maintaining solar systems. Indeed, recent experience suggests that poor installation is a far greater problem than reliability of the solar equipment itself."[1]

Thus, the report of the Energy Project at the Harvard University Business School hit on the growing problem of modern society and an important challenge to vocational education: Will we have the technical skills to succeed to move toward our goal of energy independence using new energy technologies?

Recognizing that an important key to success of developing solar technologies would be the availability of skilled labor to produce, install and maintain it, the Talcott Mountain Science Center in Avon created a unique training program for vocational-technical and high school staff. The program's goal is to develop curriculum materials which would enable vocational-technical and high school teachers to add solar energy technical training to their vocational curricula.

[1] 1979-1981 Vocational Education Improvement Projects prepared by the Connecticut State Department of Education.

ABSTRACT

TITLE OF PROJECT: A Model Solar Energy Training Program for Vocational Education Teachers - II

PROJECT DIRECTOR: Dr. Donald P. La Salle

APPLICANT ORGANIZATION: Talcott Mountain Science Center for Student Involvement, Inc.
Montevideo Road
Avon, Connecticut 06001

TOTAL REQUESTED FUNDS: $22,345.00

BEGINNING DATE: July 1, 1981

ENDING DATE: June 30, 1982

OBJECTIVES:

1. Increase number of participants from 15 to 30.
2. To codify and prepare for distribution an instructional resource guide to be used as a curriculum infusion unit by vocational education teachers.
3. To draw selected participants of the Model Solar Energy Training Program - I into the teaching scheme.
4. Conduct a series of lectures and laboratory sessions distributed geographically with the teaching actually done in the various schools represented by the participants of A Model Solar Energy Training Program for Vocational Educational Teachers - II.
5. Provide field experience by installing two solar systems at Talcott Mountain Science Center: one for hot water and one hybrid space heating.
6. Provide a conduit for university credit for teachers desiring to use this experience as part of their continuing professional growth.

PROJECT DESIGN:

The experiences, activities and curriculum materials identified as specific and useful for the needs of vocational education teachers will be used to generate the final codified instructional resource guide. The twenty-five participants in this program will be treated to a series of lectures and laboratory sessions, eight per semester, held in VT, high schools, and training centers represented by the participants. This

distributive method will provide for 1) a more equitable communting regimen and 2) ensure that the particular needs of each school setting and plant be examined by the group with possible retrofit and other energy saving acquisitions in mind.

Participants in this program wishing to register for graduate credit may do so by utilizing the opportunity offered through the University of Hartford. This course will provide the participants with sufficient knowledge of basic solar system design, fundamental and focused engineering concepts, and most important, the skills and experience derived from actually installing solar systems.

Throughout the conduct of the course, staff members of the Talcott Mountain Science Center, consultants from the field of solar system professionals operating in the state, and selected members of MSETP - I, will work to provide the participants with the awareness, skills, and confidence needed to infuse this critically important area into their existing curricula.

At the conclusion of this Project year, the Talcott Mountain Science Center will offer this program as a regular part of its University of Hartford offerings.

CONTRIBUTION TO EDUCATION:

The significance of the present energy crisis and the portent of even more dire circumstances in the near future almost mandates the need for effective energy programs in all schools.

The immediate goal of providing cost effective alternate energy sources is becoming more salient every day. It is imperative that vocational teachers be provided with proper tools and training to ensure that this information reaches the vocational student in time to meet the impending crunch for alternative sources of energy and skilled technicians to install such facilities and equipment.

The teacher training program and materials to be developed during this project will serve as a stepping stone for continued curriculum development in the vocational schools. The goals of this project will augment and supplement the long range goals of the state vocational programs and build upon the "new foundations" laid by such courses already underway.

A. INTRODUCTION

1. Statement of the Problem

The United States in general, and New England in particular, place a heavy reliance on foreign oil for hot water and space heating. There are only two likely replacements: nuclear-generated electricity and solar energy. The nuclear option is becoming less and less politically viable. However, the solar option has many desirable features. Most important it utilizes a large labor force -- labor of the kind Connecticut can make readily available.

Solar energy for space and hot water heating requires solar collectors. These are more conveniently manufactured locally, avoiding high shipping costs for bulky, easily damaged product. Furthermore, the materials are typically non-ferrous metals, and the labor is semi-skilled, matching Connecticut's traditional industrial strenghts. Installation must be done locally, of course. Currently, this is perhaps half the cost of solar energy systems. Thus, the net result of solar energy (unlike one of nuclear energy or any fossil fuel) is to consume only modest natural resources (which can eventually be recycled as scrap) and to substitute Connecticut labor in factories and at the site for either imported raw materials or high-technology manufactured products and highly technical manpower from other states.

At this time, however, solar energy is not economically attractive. The costs are all "up front" so that the solar system must bear financing costs as well as high capital costs. Capital costs must be reduced before solar energy will make a significant impact on the energy situation. The Federal Government has recently granted certain tax incentives which are intended to directly subsidize solar energy just as nuclear and other

indigenous energy sources have been subsidized in the past in an indirect manner, through oil depletion allowances, immense atomic research efforts and various Bureau of Mines efforts to help the coal industry.

The next step toward solar energy implementation will be difficult. Installation costs must be decreased, while reliability of the installed systems must increase. This is only likely to happen if mass educational programs make proper installation labor available which will not repeat past errors which to a large extent are responsible for the high installation costs.

Solar collectors could be fabricated on-site or locally near the site to reduce transportation costs and permit a cheaper but less durable product which can effectively serve as the weather protective element of the roof, further reducing net costs. Again, trained labor sensitive to solar installation requirements is needed.

Solar energy systems need specially trained labor because installation and manufacturing errors tolerable in similar technologies such as plumbing or ordinary heating lead to intolerable heat losses and system failure in solar energy systems. This has been shown on one project after another, and it is now clear that solar energy needs its own vocational programs similar to plumbing, air-conditioning and auto repair.

This proposal is intended to utilize the extensive solar energy resources at Talcott Mountain Science Center as a base for organization of a training program for high school vocational teachers so that they can teach their students about solar energy concepts, manufacturing techniques, testing, and installation in their own schools. The end product will be curriculum materials appropriate for classroom teaching.

Only if the public vocational schools enter this field can an extensive and competent labor force be developed to manufacture and install solar energy heating and hot water systems. Once solar energy becomes economical, the new industry will become very large. The addition of perhaps $5,000 - $10,000 to the initial cost of every dwelling built (not to mention retrofits) implies large additions to construction forces as local labor is substituted "up front" in place of monthly foreign oil bills.

The scope of this second year effort by Talcott Mountain Science Center was based on the following objectives:

1. To increase the number of participants from 15 - 30.
2. To codify and prepare for distribution an instructional resource guide to be used as a curriculum infusion unit by vocational education teachers.
3. To draw selected participants in Model Solar Energy Training Program I into the teaching scheme.
4. To conduct a series of lectures and laboratory sessions distributed geographically, with the teaching actually done in various schools represented by the participants in A Model Solar Energy Training Program II.
5. To provide field experience through the installation of two solar systems at Talcott Mountain Science Center, one for hot water and one for hybrid space heating.

Successful implementation of this program will result in training additional teachers to conduct solar energy vocational courses in the high schools of the 1980's. As solar energy becomes economically attractive, technicians will be needed to work in manufacturing and installing solar energy systems. It is hoped that because of this course high school teachers will be equipped to provide this training to their students.

B. SUMMARY

1. Findings

At this time last year no course in alternate energy or solar systems were being taught in the vocational-technical or regular high schools in Connecticut. Now, however, we are pleased to report that over half of the teachers who finished Model Solar Energy Training Program - I have taught energy courses this year, including courses in adult education. This is a beginning that we hope will expand with the passage of years.

We feel that this year the course has been enhanced by more work towards the practical application of solar technology rather than engineering principles, although these were still covered.

Analysis of two evaluation instruments used during the year (see Appendix A) indicates that 85% of the class felt that the level of engineering was just what was needed, 14% felt it could have been increased while no one felt it should be decreased. In contrast to last year's class, only 52% felt that the proferred level of engineering theory was needed while 38% felt it should be decreased. At the same time 85% of the class felt that the instructional staff was very knowledgeable. Probably most gratifying was the fact that all of the participants felt more confident in the area of solar energy systems with 71% feeling much more confident.

Of the twenty-five initially enrolled in the course in September 1980, nineteen were still attending in the spring. Of those that finished the course one is now teaching a course at Central Connecticut State College on solar application of domestic hot water, two have designed and constructed simple collector systems to supplement heating their homes, one has applied for a grant for his school, and several have already used activities learned with their students.

While vagaries such as snow storms and vastly different educational and experiential backgrounds of the participants occurred during the progress of the course, the pool of instructors were able to meet the individual needs of the group. This ranged from hands-on soldering techniques to reading electrical wiring diagrams and ending with the least invasive roof-penetrating techniques. Hardly the stuff that large group university lectures are made of!

In addition, toward the end of the installation of the hot water system, only a few of the participants could be involved at a time in the actual soldering and pipe fitting.

2. Recommendation

To overcome the above problems several recommendations have been made by both the instructors and participants involved in the program:

a) Set up future courses in ten to fifteen week modules.

b) Design one module for participants who need to learn the proper skills needed on the job. This module would be optional depending on background of each participant.

c) A second module would deal with just curriculum and engineering theories needed for the classroom. This could take place during winter and be required for all.

d) The third module would occur during the spring and consist of actual installations at several sites depending on available materials. Small teams of participants would work at each site under the supervision of former participants in the Model Solar Energy Training Program I & II.

It must be stressed that practical experience is a must for the teacher training. This approach would allow for greater involvement of each participant and an increased capability of relating these requisite techniques to these students.

To further insure that the vocational high school teachers and vocational-technical school teachers play a key role in making positive changes in the energy consumption and acquisition patterns now and in the future, it is recommended that a dissemination project be initiated for at least one year.

This dissemination project will allow more teachers to benefit from the experience gained by participants in both M.S.E.T.P. I & II. The dissemination project would consist of a series of workshops conducted around the state to show teachers how to use activities (Appendix B) developed during the past two projects. Workshop participants would also be made aware of resources within their state for teaching solar education.

3. Conclusion

The need for equipping teachers with the knowledge and skills to make them effective change-agents of energy acquisition and consumption patterns is clear. Economically and environmentally, we are addressing the call of alternate and solar energy sources as partial solutions to the energy problem. By providing the teachers in these institutions with the confidence, knowledge, and experience needed to infuse the sizing and application of solar systems into their existing curricula, we feel that they can make a significant contribution to the solution of our energy crisis.

To help insure this acquisition of skill and knowledge, the Talcott Mountain Science Center proposes the following:

1. The continuation of the Model Solar Energy Training Program as recommended on a tuition per participant basis.
2. To seek additional funding to run a dissemination project for the academic year 1981-82.
3. To continue revising and developing curriculum materials for uses in all classrooms.

C. PROJECT DESIGN

During the summer of 1980, Dr. Donald P. La Salle, George C. Atamian, Eric W. Danielson, Robert S. Amrein of Talcott Mountain Science Center met with participants of the Model Solar Training Program I to review the outline for the second year. At the same time, the selection of texts for the course were selected as follows:

The Passive Solar Energy Book, Edward Mazria, Rodale Press (1979) 435 pages.

Installation Guidelines for Solar DHW Systems in One- and Two-Family Dwellings, Franklin Research Center (1980) 107 pages.

1. The actual project design was set up based on recommendations outlined in the final report of Model Solar Energy Training Program I. The project was divided into a three-part program: background information for participants; activities and curriculum for the classroom; and practical experience doing installation work. Once the formal design was set up, an announcement was distributed to all vocational-technical and regular high schools in the state (see Appendix C). In addition, an announcement was sent to all applicants who were not accepted in the Model Solar Energy Training Program I. From this mailing approximately thirty-five teachers responded. In addition to the mailing, five teachers applied after hearing of the program at energy seminars they were attending. Some of the selection criteria were geographic distribution, grade and subject taught, and previous related experience. Whereas last year's program did not attract any female applicants, this year's project accepted five females. Letters were sent to those selected as participants, alternates, and otherwise (Appendix D). A list of the participants and their schools can be found in Appendix E.

The three-part design of this year's project called for three main instructors (Appendix F). Philip Fine, Vice President of the Energy Research Group of Canton, Connecticut, was selected as the engineering specialist. He is involved in site selection and sizing of solar heating and water systems for both domestic and commercial installations. His function as part of the team was to take students through the step-by-step process of system sizing and function of components. Also, he was able to supply participants with practical knowledge needed to do quality work on system sizing.

Secondly, Edward Morris, teacher at H.C. Wilcox Regional Vocational-Technical School, Meriden, Connecticut, and a participant of Model Solar Energy Training Program I served as the installation specialist. He brought with him the practical experience of teaching solar energy in the vocational classroom as well as having participated in the Model Solar Energy Training Program I. His experience with students has greatly enhanced the learning process for participants in that he is able to point out problem areas he has encountered when teaching installation techniques to his students.

The third instructor, Robert S. Amrein, Assistant Director of Talcott Mountain Science Center, served as curriculum specialist. He provided the class with activities useful in their classrooms. He also provided participants with information on where and how to obtain additional curriculum materials from a wide range of sources.

In conjunction with these instructors, three consultants were brought into the program to provide the students with additional information. One consultant, Dr. Ed Kush, was an engineer from Brookhaven Laboratories on

Long Island. He provided participants with information on new types of collectors being tested for future use and the desirability of coupling solar with heat pumps.

The second consultant, Mr. Jonathan Craig, a representative of the Northeast Solar Energy Center (NESEC) and TMSC staff member, showed the participants a new adult energy curriculum on home energy conservation. This curriculum contained step-by-step lesson plans that could be adapted to the vocational classroom. Most of the participants sent for the curriculum for their school libraries.

The third consultant, Mr Ed Butler, President of Sunrise Solar and one of the installers of the domestic hot water system in the White House in Washington, D.C. He took the participants through the active/passive solar home of George C. Atamian, Associate Director of TMSC, to examine the system installed on that site. In addition he showed step-by-step evolutionary photos of the entire job.

Classes were conducted on Tuesdays beginning September 1980 and continued through May 1981 (see Appendix G). With the nature of the New England winter weather, it was decided that we start in September with the actual installation of a domestic hot water system and study the technical background during winter months. Participants actually assembled the solar panels to be used from component parts. This probably would not be done with their classes but it was felt that it was the best way for them to understand the function of each component.

A field excursion was also taken to the Thermatool plant in Ansonia, Connecticut. This site visit afforded participants a chance to meet with designers and engineers of the second largest absorber plate manufacturer

in the United States. Participants were also shown first hand a step-by-step view of the construction of an absorber plate.

With the onset of winter, classes moved inside and worked on the fundamental concepts and techniques of system sizing. Several sessions were also devoted to looking at and testing curriculum materials for the classroom. Three of the winter sessions were devoted to sizing a building for solar space heating. In these sessions participants were introduced to the computer as a useful tool for solar. Participants learned how any school with a computer terminal could use already developed computer programs for a modest fee to insure the proper collector orientation and number of panels needed for maximum efficiency.

By early spring, participants felt that they had mastered the fundamental concepts and techniques and were able to select the components needed to complete their hot water installation. As the group was finishing up this project, other participants began looking into designing a simple, low cost, hybrid air system for a different building. The parameters for the project were that it had to be low cost and adaptable to most homes on a retrofit basis.

The final design selected was an add-on sun space with a six double glazed sun space facing south. For initial testing, no storage was recommended but a simple fan system to draw heated air into the building. As work progressed it was realized that additional man-hours were needed if they were to complete this project also. The solution was to involve students from their classes. This second project will add a testing area for storage material and will help to generate a better understanding of these systems.

The group also selected and revised twelve activities they believed could be infused into exciting vocational curricula. These activities were selected on the basis of ease of infusing and for cost of material to present (Appendix B) as well as providing a step-by-step approach for students to the areas of solar energy and DWH installation.

2. Dissemination

The existence and purpose of the Model Solar Energy Training Program was announced and disseminated via the following vehicles:

- Newspaper and newsletter articles
- Regional NESEC seminars for high school and adult education teachers
- Two 7-12 energy workshops sponsored by the State Department of Education at Talcott Mountain Science Center
- Two presentations at Vocational Program Improvement Conference

It is estimated that 200 teachers and other adults were enlightened, plus about 3,000 students were given instruction by the teachers involved.

APPENDIX A

SUMMARY
MODEL SOLAR ENERGY TRAINING PROGRAM

Phil Fine, Ed Morris, Rob Amrein
Instructors

Talcott Mountain Science Center

FINAL EVALUATION

1. Do you feel the course has evolved in the manner you expected?
   YES_____ NO_____. Please comment further:

   More math and engineering concepts than expected.

2. Is the instructor knowledgeable in the area of solar en

Very knowledgeable									Not knowledgeable
1	2	3	4	5	6	7	8	9	10
85%				7%					7%

3. How do you assess the amount and level of engineering theory presented in the course?

Increase it				Just what is needed					Decrease it
1	2	3	4	5	6	7	8	9	10
		14%		85%					

4. As a result of taking this course, do you feel more confident in teaching similar or related material to you

Much more confident				No change					Less confident
1	2	3	4	5	6	7	8	9	10
		71%	28%						

5. Do you feel this course could be taught in one semester rather than two?
   YES_____ NO_____

6. List five changes you would make in the course to enhance its success.

   (See Recommendations)

7. If your attendance in the course has been dropping off since the start of this semester, please indicate why this is so.

8. Do you feel that the adding of the solar panels on the science building will provide you with needed practical experience?

Definitely					Somewhat				No Change
1	2	3	4	5	6	7	8	9	10
	21%				78%				

9. Would you take this course if it lasted one semester and carried three graduate credits, half of which were paid for by stipend?

   YES_____ NO_____ NOT RELEVANT_____

10. Do you know any women who teach in a Vo-Tech or Vo-Ed program who would benefit from a course similar to this? If so, please indicate their name and school.

    Group response:

ADDITIONAL COMMENTS:

APPENDIX A

TALCOTT MOUNTAIN SCIENCE CNETER

MODEL SOLAR ENERGY COURSE

Participant Evaluation Form

Perspective _____

Vo-Ed Teacher High School Teacher

Instructions: To determine whether or not this program met your needs and our objectives so far, please give us your honest opinions on the design, presentation, and perceived value of this course. Please circle the number which best expresses your reaction to each of the items on this page.

EVALUATION CRITERIA

. The organization of course	Excellent 7	6	5	Good 4	3	Poor 2	1
	25%	31%	25%	18%			
. The objectives of the course were	Clear 7	6	5	O.K. 4	3	Vague 2	1
	25%	31%	37%	6%			
. The hands-on sessions for the installation so far have been	Excellent 7	6	5	Good 4	3	Poor 2	1
	18%	12.5%	31%	25%	25%		
. The session on collector efficiency was	Excellent 7	6	5	Good 4	3	Poor 2	1
	31%	31%		25%			
. The session at Mr. Atamian's house was	Very Beneficial 7	6	5	Beneficial 4	3	No Benefit 2	1
	cancelled due to snow storm						
. My attendance at this program should prove	Very Beneficial 7	6	5	Beneficial 4	3	No Benefit 2	1
	37%	31%	31%				
. Overall, I consider this program	Excellent 7	6	5	Good 4	3	Poor 2	1
	18.7%	43%	31%		6%		

. Do you feel a need for additional information on the topics covered? YES___ NO___
Which, if any, topics?

A. Please list the most valuable aspects of this workshop.

B. Please list the ways this presentation could have been improved.

C. Additional observations, please

(If additional space is needed, use reverse side)

APPENDIX B

ACTIVITIES

COLLECTOR EXPLORATION #1

SOLAR IN A COFFEE CAN

OBJECTIVE: This experiment is meant to familiarize the student with solar energy. It allows the student to perform a simple experiment by building a collector, collecting the sun's rays and measuring the heat converted by this process. The effects of glazing and insulation will be introduced in this experiment.

TEACHER BACKGROUND:

A solar collector has five basic parts. Each will be investigated in this activity.

One major part of a collector is a covering material, called glazing, which transmits as much solar energy as possible. Its purpose is to trap the energy it transmits inside the collector. The glazing should be able to withstand high temperatures without decomposing or melting, and it must be able to withstand impact from objects that might fall on it.

Another part of any solar collector is the collector plate which absorbs the energy transmitted by the glazing. The collector plate is usually coated with a dark colored material that increases the absorbance of the solar energy. The collector plate and its coating must be able to withstand high temperatures without vaporizing or otherwise breaking down. The collector plate is often made from copper or aluminum but other materials may be suitable.

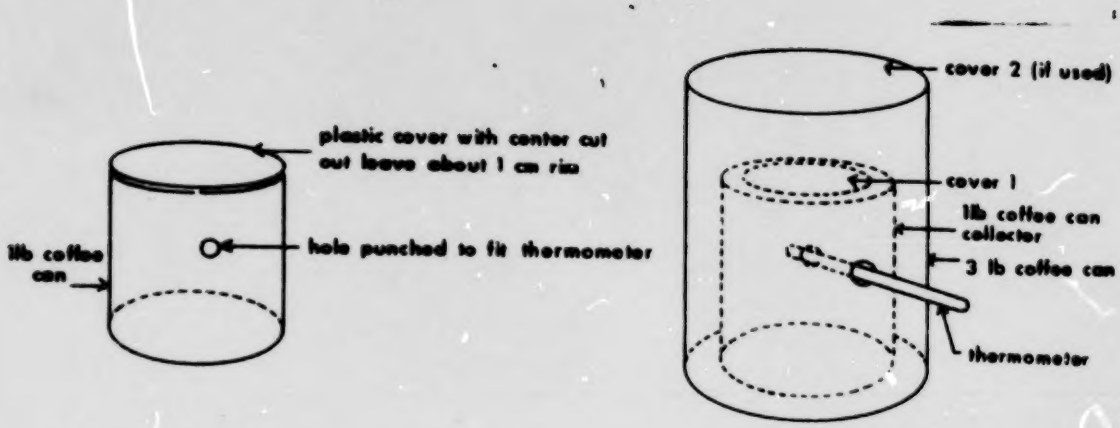
A third part of the collector, the collector box, houses the various parts of the collector. It can be made from materials such as aluminum, wood fiberglass or steel. It must be sturdy, able to withstand temperature extremes and weather conditions.

A fourth part of the collector is the insulation that surrounds five sides of the collector box. Conduction losses of trapped solar energy are substantial unless the collector box is well insulated. Fiber glass and various foams are commonly used for this purpose.

The fifth part of a collector is air or a liquid. It is used to transfer the solar energy to a system for distribution throughout the space to be heated or to a substance to be heated. If wate is used as the medium in cold climates, it is often mixed with an antifreeze.

A collector or a series of collectors can be used for space heating or to provide hot water for commercial or domestic uses.

Several weeks before the activity is planned, have students start bringing in one and three pound coffee cans with or without plastic lids.


plastic cover with center cut out leave about 1 cm rim
hole punched to fit thermometer
1lb coffee can
cover 2 (if used)
cover 1
1lb coffee can collector
3 lb coffee can
thermometer

PROCEDURE:

1. Spray the inside of the smaller can with black paint.

2. Punch a hole in the side of the small can to fit the thermometer.

3. Punch a hole in the outer can so that the thermometer can pass through it. Allow for the insulation being placed in the outer can. Small can will rest on this, not on the bottom of the outer can. Holes could be pre-punched in the cans by someone other than the students. (Use a metal punch to form the holes with an appropriate backing to avoid bending the can.) Or insert thermometers through both layers of plastic and into the center can.

4. Cut the center out of the small can's plastic lid, leaving a 1 cm rim. (See diagram above.) Use masking tape to secure the plastic to the can.

5. Choose one of the cover materials to stretch across the top of the smaller can. Hold the material secure by replacing the cut out plastic lid.

6. Put the small can inside the larger can after wrapping the smaller can with insulation.

7. Insert the thermometer through the hole in the large can and then fit it snugly into the smaller can.

8. Place the collectors in the sun and record the temperature at one-minute intervals for fifteen minutes.

9. The students may plot their data on graphs as a function of time vs. temperature comparisons of glazings and insulation types may be domonstrated in this way.

INSULATION

OBJECTIVE: Students will learn about various types of insulation and will understand current applications and limitations of their use.

TEACHER BACKGROUND:

With energy becoming an ever-increasing problem, we are continually searching for new ways to stretch our energy dollars. At present, the most cost-effective means is through the proper use of insulation. There are many forms of insulation available on the market at a variety of prices. This experiment will help students understand the uses of insulation and help them make wise decisions for their energy future.

Building suppliers and contractors often have left-over portions of insulation products which may be purchased or even donated to a good cause. After accumulating a variety of types of insulation, develop a chart with the class listing the insulations and leaving space for their uses. List each insulation material with its rated R-value per inch (if costs are available, this comparison may also be made).

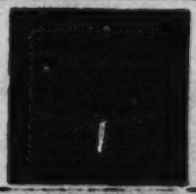
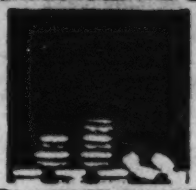
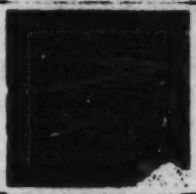
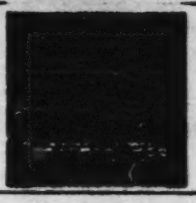
Here is a list of common insulators with R-values* per inch:

	R-value
Fiberglass batt	3.1
Fiberglass fill	2.2
Rock wool batt	3.9
Rock wool fill	2.7
Closed cell blue styrofoam	6.5
Styrofoam board	4.5
Polyurethane foam	4.5
Isocyanurate foam	7.3
Urea formaldehyde (Due to shrinkage following installation, actual R value is slightly less.)	4.2
Cellulose fibrefill (contains boric acid)	3.7
Vermiculite	2.2
Perlite	2.7

*R-value = resistance to heat flow (BTU/hr/F^{o}/ft^{2}).

Discuss possible uses for all insulations such as building exteriors and interiors, hot-air duct work, plumbing for heating systems and solar applications. Discuss what makes a good insulator.

Types of insulation

Form		Method of Installation	Where Applicable	Advantages	Materials
Blankets or Batts		Fitted between wood-frame studs, joists, and beams	—All unfinished walls, floors, and ceilings	—Do-it-yourself —Best suited for standard stud and joist spacing, which is relatively free from obstructions —Blankets: Little waste because it's handcut —Batts: More waste, but easier to handle than large rolls	Rock wool Glass fiber
Loose Fill (poured in)		Poured between attic joists	—Unfinished attic floors and hard-to-reach places —Irregularly shaped areas and around obstructions	—Do-it-yourself —Easy to use for irregularly shaped areas and around obstructions	Rock wool Glass fiber Cellulose fiber Vermiculite Perlite
Blown Fill		Blown into place by special equipment	—Anywhere that frame is covered on both sides, such as side walls —Unfinished attic floors and hard-to-reach places	—The only insulation that can be used in finished areas —Easy to use for irregularly shaped areas and around obstructions	Rock wool Glass fiber Cellulose fiber Urea-formaldehyde foam (not recommended for unfinished areas)
Rigid Insulation		Must be covered with ½-inch gypsum board or other finishing material for fire safety.	—Basement masonry walls —Exterior walls under construction	—High insulating value for relatively little thickness	Polystyrene board Polyurethane board Isocyanurate board

Source: DOE Insulation Fact Sheet

PROCEDURE:

1. Test under hood or outdoors each type of insulation in an open flame (Bunsen burner or small torch). Note that some types give off black smoke and burn readily. What does this tell the student about where an insulation may or may not be used? (Many victims in large hotel fires died from noxious insulation fumes.)

2. Heat a hot plate (solid plate burner) or electric iron to 200°F and touch a piece of each insulation material to it. (Vinyl and polystyrene should melt). In many heating systems and solar applications 200° may be reached, although often with water systems the temperature is kept below this to prevent steam and overpressure of the system. Increase the heat source to 350°F and fiberglass with bonding material will outgas and urethane and isocyanurate will begin to break down.

In collector systems, temperatures may reach above 350°F so high-temperature fiberglass without bonding agents and isocyanurate with foil backing are often used in collectors.

3. Fill a glass or plastic container with water. Weigh a small portion of each insulation then submerge it in water, weighing

again after submersion. Those insulations that absorb water will become ineffective in exterior applications. Test urethane and isocyanurate last. Using litmus paper, test the water from these two insulations. (Litmus will turn red as they form an acid.)

4. As a long term experiment (3-4 weeks), leave insulation exposed to sunlight and determine degree of breakdown.

5. Summarize properties and discuss proper applications for each insulation and use R-value and cost comparisons to determine most economical uses.

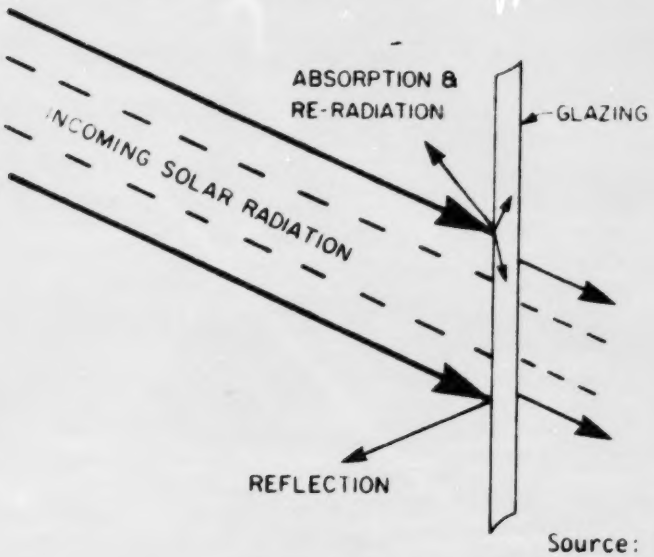
GLAZING

OBJECTIVE: The student will be able to test a variety of glazings for transmisivity and the various properties related to heat and solar exposure.

TEACHER BACKGROUND:

As we learn more about using the sun's energy, windows and solar collector glazings become more significant. Any form of glazing has very little merit as an insulator (R-value = .9). Glass is used for coffee pots and other cooking devices indicating its conductive qualities. In warm weather climates, single glazing or even just a screen may be adequate to keep comfortable. However, in northern temperate climates such as our own, another layer of glass means twice the protection from the outside cold and in some instances, three layers may be recommended.

TRANSMITTANCE LOSSES



Source: Northeast Solar Energy Center

Glazing comes in many different types, each having favorable and unfavorable characteristics such as breakability, resistance to heat, durability against weather and weight and transmisivity. As in the insulation activity, a chart can be made listing the properties of each type of glazing.

Many different types of glazings can be obtained from storm door and window manufacturers for a nominal fee or perhaps even donated. (See List)

PROCEDURE:

1. Using a light meter or a photometer test each glazing for transmisivity of light. This might best be done using a test stand (ringstand with clamp) at a set distance from a laboratory spot-light. The distance may be set by approximating the intensity read by the meter in natural sunlight.

2. Test the glazings with 2 or 3 layers and note the losses. Would south-facing windows or solar collectors be triple glazed? Why? What applications would exist for triple-glazed windows?

3. Using a hot plate, test synthetic glazings for 200° and 350° temperatures. Note shrinkage or expansion and warping of certain materials and the effect this might have on collector performance. Note that in some materials, transparency will begin to degrade. Some solar collectors may be at 300° for each day of an entire summer.

4. Using properties from this experiment, summarize the results and discuss the proper use and applications of different glazings. It may also be useful to determine cost comparisons.

COMPARISON OF GLAZING MATERIALS

GENERAL TYPE	TRADE NAMES	COMMENTS	THICKNESS (inches)	[illegible]	[illegible]	MAXIMUM OPERATING TEMPERATURE (°F)	ESTIMATED LIFETIME (years)	$ SQUARE FOOT	TRANSPARENT	TRANSLUSCENT	POUNDS SQUARE FOOT
GLASS	[illegible]	ADVANTAGES • Excellent Transmissivity Characteristics • Superior Resistance to Heat, U V, Abrasion	1/2"	84	< 3	400+	25+	1 00	X		1 60
	STRENGTH										
	[illegible] GLASS UNITS	• Low Thermal Expansion Coefficient • Easily Available • Transparent	.625	[illegible]	< 3	200	25+	3 50 7 00	X		5
	[illegible]	DISADVANTAGES • Difficult to Site Fabricate • Low Impact Resistance • Cost	187	91	<3	400	25	2 25		X	2 4
PLASTIC	[illegible] PLEXIGLAS LUCITE ACRYLITE	ADVANTAGES • Excellent Transmissivity Characteristics • Superior U V & Weather Resistance • Won't Yellow	125	[illegible]	< 5	180 200	20+	2 00	X		72
	[illegible] SCALE LUCITE SDP	• Lightweight • Easy to Site Fabricate DISADVANTAGES • Susceptible to Abrasion • High Expansion/Contraction Rate • Slight Embrittlement with Age • Cost • Relatively Low Service Temperature	.625	[illegible]	< 5	160	20+	3 00 4 00		X	1
POLYESTER	MYLAR	ADVANTAGES • Low Cost, Clear Glazing • High Service Temperature	001 005	85	50	250	2	08 35	X		25 oz. 10 oz.
	LLUMAR (U V RESISTANT)	DISADVANTAGES • U V Degradable Unless Treated • Optical Clarity is Distorted due to Thickness of Material	0005 014	88	N/A	350	10	50	X		

COMPARISON OF GLAZING MATERIALS

			THICKNESS (inches)	SOLAR TRANSMITTANCE (%)	IR TRANSMITTANCE (%)	MAXIMUM OPERATING TEMPERATURE (°F)	ESTIMATED LIFETIME (years)	$ / SQUARE FOOT	TRANSPARENT	TRANSLUSCENT	POUNDS / SQUARE FOOT
POLYCARBONATE	LEXAN MERLON DOUBLE WALL LOFTAK SWINWALL MARLEX	ADVANTAGES • Excellent Service Temperature • Highly Resistant to Impact DISADVANTAGES •Poor Weatherability & U V Resistance (Yellows) • Scratches Easily • Not Easily Available • High Expansion/Contraction Rate	.125 .220	82 79	6 < 8	270 270	10 15 5-7	3.25 1.75 3.00	X	X X	75 25
FIBER REINFORCED POLYESTER[3]	KALWALL FIBRON KALWALL DOUBLE WALL KALWALL FIBER PANELS	ADVANTAGES • Low Cost • High Strength • Superior Weatherability (Teflon coated panels only) • Easy to Fabricate and Install DISADVANTAGES • Susceptible to U V, Dust & Pollution Degradation • Yellows with Age • High Expansion/Contraction Rate	.040 .040 .040 .040	81 82 79 70	< 10	160 160 400 N/A	15 15 12 12	60 85 85 5.00		X X X X	5 oz. 4 oz. 5 oz. N/A
LAMINATE ACRYLIC POLYESTER	FILMOLUX	ADVANTAGES • Combines Weatherability of Acrylic with High Service Temperature of Polyester • Good Transmissivity Properties DISADVANTAGES • Non Reversible • Susceptible to Wind Flapping	.007	81	9.5	275	10	40	X		5 oz.
POLYETHYLENE	VISQUEEN MON. ANTI-FOG (U V RESISTANT)	ADVANTAGES • Inexpensive • Easy to Install • Easily Available DISADVANTAGES • Poor U V and Weather Resistance • Low Service Temperature • Cats LOVE to climb on the stuff	.006 .006	90 87	> 70 	140 < 160	8 mos. 2-3 yrs	.02 .08		X X	5 oz. 5 oz.
FLUOROCARBONS	TEDLAR PVF	ADVANTAGES • Excellent Weatherability • Strong • High Solar Transmission DISADVANTAGES • High I R Transmission • Not Easily Available • Susceptible to Wind Flapping	.004	90	50	300	10	.50		X	.5 oz.
	TEFLON FEP	ADVANTAGES • High Solar Transmission • High Service Temperatures • Long Life DISADVANTAGES • Same as Tedlar PVF • Poor Tear Resistance	.001	96	50	400	25	.50	X		
SILICONE COATED CLOTH	DOW CORNING	ADVANTAGES • Good Transmissivity Characteristics • Excellent Service Temperature • Extremely Weatherable DISADVANTAGES • Susceptible to Wind Flapping and Tearing	.008	90	10	500+	15+	1.00		X	.5 oz.

ABSORPTION MEASURING HEAT OF COLLECTOR WITH A THERMOCOUPLE

OBJECTIVE: A student will be able to test the properties of different absorber materials and the absorbancy of different colors for solar collectors.

TEACHER BACKGROUND:

Copper is the most widely used material for solar absorbant surfaces. This material is compatible with standard plumbing practices and is a good conductor of energy. Other materials have been used with limited success such as aluminum, galvanized sheet metal, plastics and rubber mats. Future projects seem to be leading toward thin polymer metal combinations which will have little or no possibility of corrosion or breakdown. Surfaces of the absorbers may be chemically bonded or have etched surfaces such as selective black nichrome or selective paints. Selective surfaces not only have good absorbancy qualities, but also have a low emisivity or rate of reradiation. Students may test different colors and gloss vs. flat colors. Each paint has its own set of properties so no one factor can determine its performance on the absorber surface.

This experiment uses a thermocouple to measure heat. Thermistors similar to this are used in solar collectors to trigger the differential thermostat mechanism in a solar system controller.

A thermocouple is made up of two different types of wire twisted together. Heat added to this coil creates an electrical current. Using two coils with one at a given reference temperature, temperature can be easily determined. A table for temperature readings ($0^{o}C$ or $32^{o}F$) of a copper constantan thermocouple using ice water as the reference temperature is given below. Other thermocouple combinations may be used but a different table must be used for your results. Copper constantan is one of the most common combinations and most suitable for the temperature range of this experiment.

TEMPERATURE - VOLTAGE READINGS FOR A COPPER - CONSTANTAN THERMOCOUPLE

^{o}F	^{o}C	MILLIVOLTS	^{o}F	^{o}C	MILLIVOLTS
0	-17	-.67	110	43	+1.75
10	-12	-.47	120	49	+1.99
20	-6	-.26	130	55	+2.23
30	-1	-.04	140	60	+2.47
32	0	.00			
40	5	+.17	150	66	+2.71
50	10	+.39	160	71	+2.96
60	15	+.61	170	77	+3.21
70	21	+.83	180	82	+3.46
80	27	+1.06	190	88	+3.71
90	32	+1.29	200	93	+3.97
100	38	+1.52	210	99	+4.22
			400	190	+20.00 max range

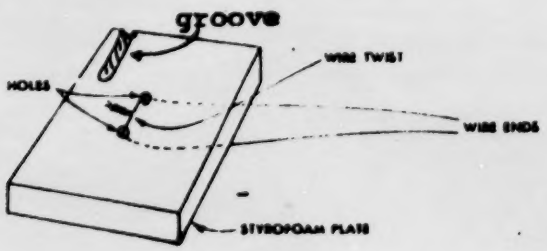
PROCEDURE:

Each group will need one meter of copper/constantan thermocouple wire, a millivolt meter, a piece of styrofoam (5cm X 60cm X 60cm), a metal absorber 60 X 60 cm (copper flashing, aluminum flashing or foil, galvanized steel, or sheet metal may be used.) Try to determine what effect metal thickness has on absorber efficiency.

1. Carefully take the piece of copper wire and cut it into two pieces, one slightly longer than the other.

2. Take the end of the longer copper wire and twist it together with the constantan wire so that about ten tight turns are made (you may need pliers).

3. With a nail, make two holes in the sheet about 2 cm from each other and near the center. Feed the ends of the twisted wire through the holes as far as they can go without untwisting the two wires. (See figure 1) Also cut small groove to fit thermometer.



4. Take the end of the constantan wire which is not twisted and twist it together with the smaller piece of copper wire in the same fashion that you used in step 2.

5. Place this twist in the insulated container filled with ice and water. It helps to make a styrofoam cover to improve the insulation of the container.

6. Paint aluminum with black spray paint on one side.

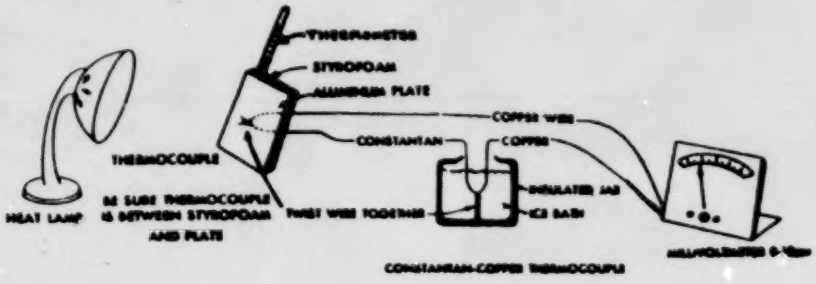
7. Carefully glue (in 2 or 3 spots only) the aluminum foil to the outside of the styrofoam sheet, painted side up, to serve as an absorber plate. Be careful not to rip the aluminum foil on the rough edges of the wire. Test surfaces other than aluminum foil such as copper sheeting, galvanized steel, or sheet metal. Use colors other than black and compare your results.

8. Place the voltmeter between the two copper wires that are not attached. If the voltmeter does not read a value, switch the

terminals so that the volt reading is positive. (See figure 2)

9. CAREFULLY take your equipment outside. (If no sun is available, use heat lamp inside).

10. See figure 2 for an illustration of this activity.



11. On a data sheet, record the voltage reading every minute for fifteen minutes.

12. Carefully take your equipment apart so that all the pieces may be used again.

13. Using the conversion scale, determine the approximate temperatures which your collector had during each interval that you measured. Place this beside your voltage reading on your data sheet.

14. Plot the data, temperature vs. time on a graph.

15. Insert thermometer in groove behind plate and record the actual temperature vs. the calculated temperature.

COLLECTOR EXPLORATION #II

HEAT LOSS AND STORAGE IN A SIMPLE SOLAR GREENHOUSE

OBJECTIVE: The student will be able to build a simple testing structure. From this apparatus, the student will learn the principles of the "greenhouse effect" and be able to test different materials for thermal storage.

TEACHER BACKGROUND:

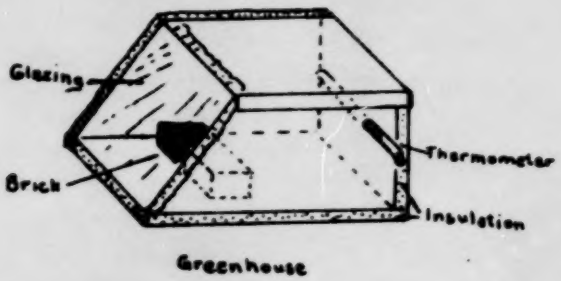
All solar heating systems utilizing sunlight must convert that energy through a process called the "greenhouse effect". Simply stated, light energy trapped in a solar collector is absorbed. The absorbing surface reradiates this energy in a longer wave-length (infrared) and the infrared energy is trapped by the glazing with only a portion escaping. This trapped energy is then reabsorbed as heat in the collector

A greenhouse, then, is a form of solar collector constructed so that all of its glass heat may escape through conduction. When the sun does not shine, the greenhouse's losses will be greater than its gains and it will get colder than most plants can stand. Many greenhouses bring in more energy than they can use during a sunny winter period and the excess energy is vented to the outside. Materials placed in the greenhouse to absorb this excess energy and later redistribute it at night may help us better utilize the sun's energy.

PROCEDURE:

Collect materials such as concrete or broken cinder block, brick, small stones and cans or film canisters filled with water. Discuss density, thermal mass and specific heat as factors for heat storage.

1. Construct a greenhouse using a shoebox or similar size cardboard container. See Diagram.



2. Insulate all sides of your box with 1" styrofoam or fiberglass

insulation around the outside.

3. Paint the inside flat black and cover the diagonal opening with 5mil plastic sealed to the box. The top should be made moveable in order to replace storage materials.

4. Place the box in sunlight or under a lamp. For ten minutes, record the temperature from the thermometer in top of box (out of direct sunlight) at one-minute intervals. Shade the box for 10 minutes and continue to record the temperature at one-minute intervals. The temperature should fall quickly.

5. Try each type of storage material in the box where sunlight can shine on it directly. Again test for 10 minutes.

6. Determine which storage holds the most heat for the longest period of time, whether water is better than stone, and if solid blocks are better than fragments.

COLLECTOR EXPLORATION #III

BUILD A SIMPLE HOT AIR COLLECTOR

OBJECTIVES: Students will be able to build and test a simple air flow collector. Information found in previous experiments will help the student to make better judgments in this one. Students will evaluate their collectors for heat output and efficiency.

TEACHER BACKGROUND:

The solar collector is a device for transforming light energy to heat energy and thus raise the temperature of the transport medium. Visible light rays enter the collector through glazing material. Upon striking the absorber plate, some of these rays are absorbed as heat and others are absorbed and reradiated as longer wavelength infrared rays. A black surface increases the efficiency of the process, while the insulation and glazing keep these heat rays inside the collector. The input hole allows outside air in. This air is heated while inside the collector and because hot air is less dense, it will rise and escape by convection through the upper hole for output. When properly functioning, the flat plate air flow solar collector will have an output air temperature substantially higher than the input temperature.

Any solar collector regardless of size or complexity always contains the following five elements: a collector box, glazing, an absorber plate, insulation, and heat transfer medium such as air, water, etc.

Students may build collector box or teacher may supply a pre-fabricated one to be used for future classes. If possible, make available a variety of glazing and insulation materials in order to allow students to make decisions based on previous experiments.

PROCEDURE:

1. Build a box of 1/4" to 1/2" plywood or pine, 4" deep and 12" wide and 16" long as inside dimensions. Cut insulation to fit 12 x 16 dimensions.

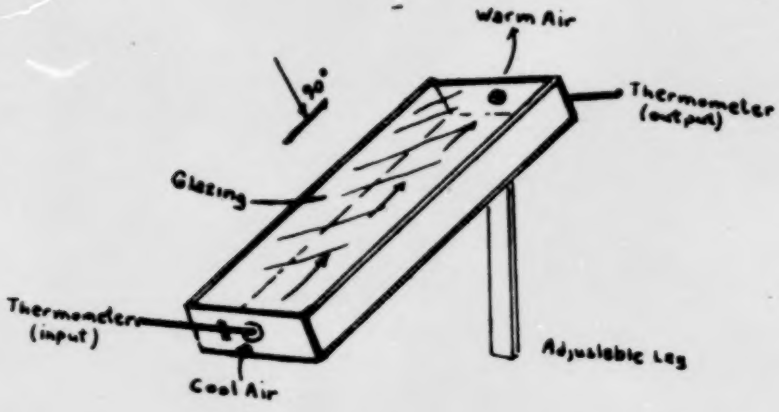
2. Cut glazing slightly larger to overlap sides. Drill a 1" hole centered in either end of the box. Absorber may be foil backing on insulation or aluminum foil cut to fit.

3. Paint the absorber surface and assemble the collector.

4. The glazing may be taped with masking tape and a thermometer should be taped in place at each hole to record input and output temperatures. Students should take extreme care if glass laboratory thermometers are used. Thermometers with a range of -10° to $110^{\circ}C$ or 20 to $220^{\circ}F$ provide an adequate range for outdoor winter and summer conditions.

5. Place collector in sunlight and adjust to an optimum angle to obtain the most sunlight. The angle perpendicular to the sun will change throughout the day and year. Tests could also be made with collectors facing south at an angle best suited to winter (latitude $+10^{\circ}$).

6. A reading should be taken from each thermometer every two minutes for at least 20 minutes. Shorter periods may be used but will not show maximum performance. Collector data may be graphed with an axis for time and temperature.



COLLECTOR EXPLORATION #IV

SOLAR HOT WATER

OBJECTIVE: Students will learn the principles of heating water with a flat plate solar collector, properties of water storage and thermosiphoning are also explored.

TEACHER BACKGROUND:

From previous experiments, the students will have developed tables of materials used in solar collectors. Now all of the components may be assesbled. Decisions regarding which materials are to be used may be made as a class or by instructor previous to class based on availability.

Many different designs have been developed for flat plate collectors. Basically, the flat plate collector is a device which absorbs the energy falling upon it and transfers this energy to the transport medium. No attempt is made to concentrate the sun's energy on a smaller area; as a result, the maximum operating temperature of the fluid in a flat plate collector is usually less than 65°C (150°F). The collector consists of an enclosure, insulation, glazing and a flat plate with tubing to carry the heat transfer medium.

Schematic Diagram of Cross Section of Flat-Plate Collector

The surface area required of the solar collector varies with geographic location. A very rough rule of thumb is a one to three ratio of collector area to living space. In the colder regions of the country it is still not economical to rely on solar heat for more than 50 percent of the total space heating required. Domestic hot water heating by solar energy is competitive at present with electric hot water systems in much of the country. Solar collectors now cost roughly $\$10/ft^2$; entire systems \$20 to $\$40/ft^2$. Costs, however, are subject to rapid change. Systems integrating solar cooling with solar heating may require the concentrator-type collector because of the need for water temperatures of 93°C (200°F) or more.

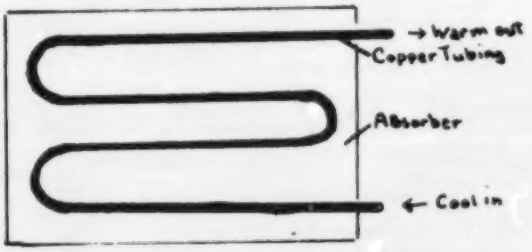
MATERIALS USED IN FLAT PLATE COLLECTOR CONSTRUCTION

COMPONENT	MATERIALS USED	COMMENTS
Container:	Metal (Aluminum, galvanized steel)	Lightweight, durable.
	Fiberglass	Many plastics deteriorate rapidly on exposure to ultraviolet radiation.
	Plastic	
	Wood	May deteriorate because of high stagnation temperature (350°F) and moisture condensation.
	(There is no standardized size for single units: a 4 x 8 ft. unit is difficult for two persons to handle: 4 x 4 ft. units are often used. 2 x 3 ft. units may be used to take advantage of local availability of this size sheet metal.	
Insulation:	Fiber glass (glass wool)	Has relatively high insulating value, stable.
	Polyurethane foam	Expensive, deforms over 160°F.
	Styrofoam	Flammable.
	(Two to four inches of fiberglass insulation should be used.)	
Glazing:	Glass (many types available)	Probably best, but costly and breakable.
	Low iron glass (looks blue on edge)	.88 transmittance, common.
	Water white crystal (ASG)	.92 transmittance, costly.
	(Glass thickness should be 1/8" or 3/16"; double glazing with one inch air space needed in colder regions or if temperature over 160°F are desired.)	
	Fiberglass ("Filon", "Kalwall")	Good, but some loss of transmittance with ultraviolet aging (special ultraviolet resistant types available at higher cost.)
	Polycarbonates ("Lexan")	Good, but very expensive.
	"Mylar", "Tedlar" sheeting	Reradiate infrared; mylar undergoes ultraviolet degradation.
	Polyethylene Film	Poor, short life (1/2 yr.) transmits up to 70% infrared (this represents a heat loss.)
Flat Plate:	Copper	Probably best.
	Aluminum	Corrosion problems if contact with other metals.
	Steel, galvanized	Poorer heat conduction, may rust eventually.

COMPONENT	MATERIALS USED	COMMENTS
Tubing:	Copper Aluminum Plastic	Best. Possible corrosion problems. Poor heat transfer, low temp. use.
Paint:	3M "Nextel" or "Black Velvet" Flat Black	.98 absorptivity with 93. emissivity, expensive. Should stand 400°F
Selective Coating:	Black Chrome Nickel Black Black Copper Oxide	Best, durable, .90 absorptivity and .15 to .35 emissivity, but very expensive.
(Selective coatings increase efficiency dramatically when there is a large temperature difference between the collector plate and outside air. For low temperature collectors the extra cost is probably not warranted.)		
If the heat transfer medium is air instead of liquid, then no tubing is required and just the flat or corrugated sheet, with or without baffles, is used.		

PROCEDURE:

1. Depending on age and skill level of students the absorbers can be made previous to class by the instructor or as part of the activity. A 12" x 16" absorber may be cut from galvanized steel or sheet copper. Make a serpentine pattern on the absorber with a pencil (See diagram).



2. Bend 5 ft of soft copper 1/4" or 3/8" tubing using a tubing bender on a flat table into the pattern indicated above. Allow 2 inches on each end for connection of rubber tubing.

3. Take a one-pound coffee can and drill holes in the sides and top and bottom to accommodate small nipples (2" each) cut from copper tubing.

4. Using a flux and 60-40 or 50-50 solder copper tubing onto plate.

Expansion and contraction during heating will cause plate to buckle. To minimize this, clamp tubing to the plate at 10-inch intervals or as needed. Make sure soldering is done on a non-flammable surface.

5. After absorber is soldered, solder nipples into can, allowing them to project 1/4" inside can. Check for leaks.

6. Cut insulation 12 x 16 and glazing slightly larger. Construct a box the same as in the previous activity. Drill holes to accommodate ends of tubing from absorber plate. Box sides may be slotted to accommodate absorber plate and glazing or absorber may rest on insulation with glazing taped on top of the box.

7. After collector is assembled, attach 2 feet of rubber tubing to the bottom of the can and the bottom of the collector. Attach a second piece to the top of the collector. (Can must be above collector.)

8. Place collector in sunlight or under a heat lamp. Fill can with water and collect heated water at top in a second container of same size. Measure temperature in top and bottom cans. Temperature may be increased by pouring heated water through several more times. The average temperature change (T) may be calculated for each cycle. (Bottom input - Top output = T.)

THERMOSIPHON METHOD

1. Connect rubber tubing from the top of the storage to the top of the collector and fill the storage container to above the top fitting.

2. Allow to stand in sunlight for 20 minutes.

3. Record the temperature change every 2 minutes. Storage must be above the collector in order for the thermosiphon to circulate. Also, the collector should be tipped back and forth to allow any air to escape from tubing. The storage tank should be insulated for better efficiency. Make comparisons to a domestic hot water system.

PLUMBING AND INSULATION

OBJECTIVE: This demonstration will show the student the properties and proper use of different insulations for application to solar plumbing situations. Students will have already tested these materials for heating and weathering properties in a previous session.

TEACHER BACKGROUND:

Plumbing insulation is one of the most commonly overlooked or improperly installed materials in a typical solar installation. As demonstrated in a previous activity, many insulations cannot stand up to high temperatures which may be reached under conditions of stagnation in a solar heating system. Many types breakdown in ultra violet light, others are not water resistant and when wet may produce corrosive materials which may react with plumbing. Manufacturers of plumbing insulations have solved many of these problems, but care still must be exercised when selecting insulations. Most insulations are applied with a protective plastic covering with a tight seal for exterior uses.

In a solar hot water system all exposed pipes except for cold water supply should be insulated. All hangers should be isolated from pipe by insulation since each may act as a potential heat sink.

The most common pipe insulation materials are fiberglass, eslatomers, (Armaflex, Rubatex, etc), urethane, and isocyanurates. As shown previously application depends on availability, cost, insulating qualities, and durability of materials.

Covering materials may be a plastic or aluminum jacket or in some cases just paint will be enough. Aluminum and plastic covers are most often pop-riveted and sealed with silicone and or weather resistant tape (duct tape should not be used for this purpose).

PROCEDURE:

INSULATION PLUMBING

1. Prepare a board showing major pipe insulation systems. Demonstrate by passing samples around. Discuss sealing, fastening, tapes, hangers.
2. Emphasize importance of insulation. Discuss minimum thickness inside and outside for pipes; durability and costs of the recommended insulation.
3. Extend discussion to storage tank, including installation techniques. Show polystyrene foam and the way to use it as a second layer on storage tank.
4. Discuss underground lines. Show sample of pre-insulated pipe for underground use. Elastomerics should not be used for underground applications.
5. Set up an insulated tank and fill with hot water. Find its time constant and calculate the heat loss coefficient.

PLUMBING AND PIPES

OBJECTIVE: Students will know the different types of plumbing used in solar applications. They will discover what electrolysis and galvanic action are and will learn proper solder use and techniques.

TEACHER BACKGROUND:

Plumbers have followed many common sense guidelines for years, but in many solar applications these guidelines have been overlooked or perhaps need modification to meet the new applications of a solar hot water system. One rule of thumb is not to mix unlike metals. Still many solar systems have cast iron pumps mixed with copper plumbing. Some collectors have used aluminum and copper together resulting in very short life of the system. Use the accompanying table to explain electrical potentials of metals. Galvanic action is a process by which one metal is attracted to and plated on to another. Water by itself is not a good conduct r, but with acid fluxes, and chemical changes in a solar system galvanic action and oxidation can cause major problems with a system.

GALVANIC SERIES OF METALS

Anodic or Least Noble End

GROUP	METAL
a.	Magnesium
b.	Zinc
c.	Aluminum 2S
d.	Cadmium
e.	Aluminum 6063 -
f.	Steel Iron Cast Iron
g.	18-8 Stainless Steel (active)
h.	Hastelloy
i.	Lead/tin solder Lead Tin
j.	Nickel (active)
k.	Brass Copper Bronze Copper Nickel Alloys Monel
l.	Silver solder
m.	Nickel (passive) 18-8 Stainless Steel (passive)

Cathodic or Most Noble End

RECOMMENDED TYPES OF PLUMBING

The most favored plumbing for solar DHW systems is sweat-soldered, L-type copper tubing. M-type copper is also acceptable if it is allowed by local building codes.

All joints in copper tubing in and near the collector array should be soldered with 95-5 tin-antimony solder to avoid joint failure at stagnation temperature. While 95-5 could be used throughout the rest of the system and should be used in a silicone system, 50/50 tin-lead solder can be freely substituted in those parts of the system that will not be subjected to the extremes of stagnation temperature. Remember that silicones and glycols demand well-soldered joints.

The following table indicates common solder types and their respective melting temperatures and metalic makeup.

TIN	LEAD	ANT	SOLID	LIQUID
63	37		361	361
60	40		361	374
50	50		361	421
45	55		361	441
40	60		361	460
95		5	452	464
Melting point of solder			Paste range	

Although soldered joints are preferred, threaded joints may be made with a good quality joint compound and/or Teflon^{R} tape. Examples of quality joint compounds are: Loctite^{R} pipe dope with Teflon^{R} (Part No. 529), Crane^{R} Je-30 pipe thread sealer with Teflon^{R}, Rector^{R} Seal No 5, and Dow Corning^{R} 730 Fluorosilicone rubber sealant, and their equivalents.

CAUTION: If the heat transfer fluid is a silicone or a water/glycol solution, standard pipe dope WILL NOT prevent leakage.

PLASTIC PIPE

Do not use PVC for hot water applications. CPVC will sag about 160^{o} F, if not adequately supported, thereby preventing draining of draindown systems, making flushing out of non-draindown systems more difficult, and preventing air bubbles from venting properly. Polybutylene pipe will begin to sag at about 200^{o} F. In general, use extra care when using plastic pipe.

GALVANIZED THREADED PIPE

Convential galvanized threaded pipe may be used if already installed in the existing DHW system. All threaded joints should be thoroughly pipe doped.

SILICONE COUPLING HOSES

Silicone coupling hoses are sometimes recommended by the manufacturer for connecting collectors to the array manifold or to act as expansion joints in the hot water return circulation. Those hoses can also be used between plumbing of dissimilar metals to retard galvanic corrosion.

CAUTION: Ordinary automobile radiator hoses should never be used, as they break down rapidly when exposed to the ultra violet waves in sunlight.

Silicone hoses should be clamped with lined stainless steel hose clamps without the usual perforations. The rubber will extrude through the perforations.

HANGING AND ANCHORING PIPE

Pipe hung vertically should be anchored at the following intervals:

Copper Tubing - one story or ten-foot intervals

Threaded Pipe - every other story

Rigid Plastic Pipe - half-story intervals

Pipe hung horizontally should be supported at the following intervals:

Copper Tubing - eight-foot intervals, for drawn tube, six-foot for annealed tube

Threaded Pipe - twelve-foot intervals

Rigid Plastic Pipe - one-to-two foot intervals

EXPANSION - All pipe should be hung or anchored loosely enough so that it can expand and contract with temperature changes. A 100' length of copper pipe will expand approximately 1" with a 100° F. temperature rise. Using silicone hoses as expansion joints is advised in arrays where there is no room for pipe expansion. Standard corrugated expansion joints made of copper alloy are also available. Elbows will also allow for some expansion.

INSTALLATION TIPS - Keep insides of all tubes or pipes clean and ream out the ends of all pipes and tubing. Sandpaper or emery cloth the outside surface of the ends of copper tubing and the inside surface of all copper fittings before soldering. Surfaces must have a bright finish. Bend copper tubing (providing it is annealed or bending temper tubing) rather than use elbows or other fittings. This will reduce friction losses. Avoid sharp bends and use bending tools. Use eccentric reducers to join horizontal pipe of different sizes and avoid trapping air (Figure 3.1).

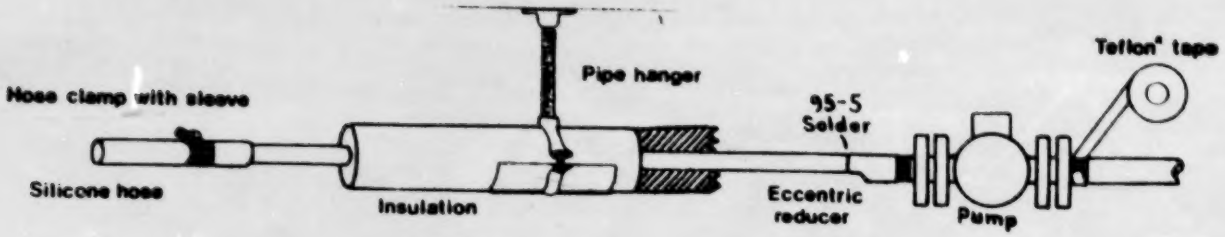


FIGURE 31 PIPE LENGTH AND VARIATIONS

PROCEDURE:

1. Prepare a board showing all common copper fittings in the 1/2 and 3/4 inch sizes, with a few black iron and galvanized fittings as well.

2. Demonstrate proper solder techniques, preferably letting the students make up joints with 95-5 solder. Stress the importance of proper temperature. Discuss silver/tin and silver/copper solders and their applications; fluxes and cleanings.

3. Demonstrate polyethylene and other useful plastic tubes and joints. Demonstrate proper fittings for silicone hoses.

4. Discuss types of pipe thread compounds and their applicability. Show samples of caulking sealants - urethane and silicone in particular - their usage and applications.

A SOLAR INSTALLATION SITE PLAN

OBJECTIVE: At the completion of this activity, students will be able to obtain a true north-south line to determine best solar orientation and determine the path of the sun across the sky at chosen site for mid-winter heating needs. This will help them to decide upon a plan to improve a site for a solar installation. Students may take this activity home to help make a solar plan for their own home site and make recommendations for improvement of their respective home sites.

TEACHER BACKGROUND:

The way in which a building is oriented is critical for the potential use of solar energy. In this activity students learn what is the best orientation for a new home or make an analysis of an existing structure such as their own home or school. Factors such as local climate and seasonal changes in the sun's path must be taken into account.

For both active and passive solar use a collector which should be oriented true south. Collectors 15^0 to the east or west of south perform nearly as well. With roofs of existing structures greater than 15^0 from south special mountings for solar collectors would have to be considered at an added expense.

Because the earth's magnetic field is not aligned parallel with the earth's north-south axis, there are some parts of the United States where the needle of a magnetic compass can point as much as 20 degrees east or west of true north. However, there are several ways to determine the true south in your area. You can consult a local surveyor, a plot map in your local tax office, or a recent isogonic chart of the United States published by the U.S. Coast and Geogetic Survey, U.S. Department of Commerce (Figure 1.7) and adjust your magnetic compass reading according to the meridian nearest to you. Don't use old charts, as there are annual variations in the readings. When using a magnetic compass, beware of standing near large metallic objects or power lines because they will affect the compass readings.

Also, you can easily determine true south yourself, right at the installation site. Place a stake in the ground and mark the location of the shadow on the top of the stake. Connect the end point of a morning shadow with the end point of an afternoon shadow by a straight line. A line drawn 90^0 to that line is a true north-south line. (Figure 1.8)

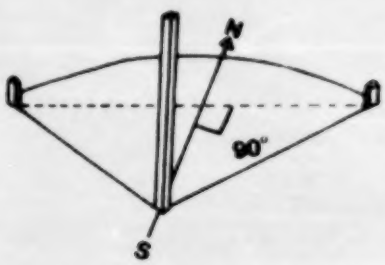
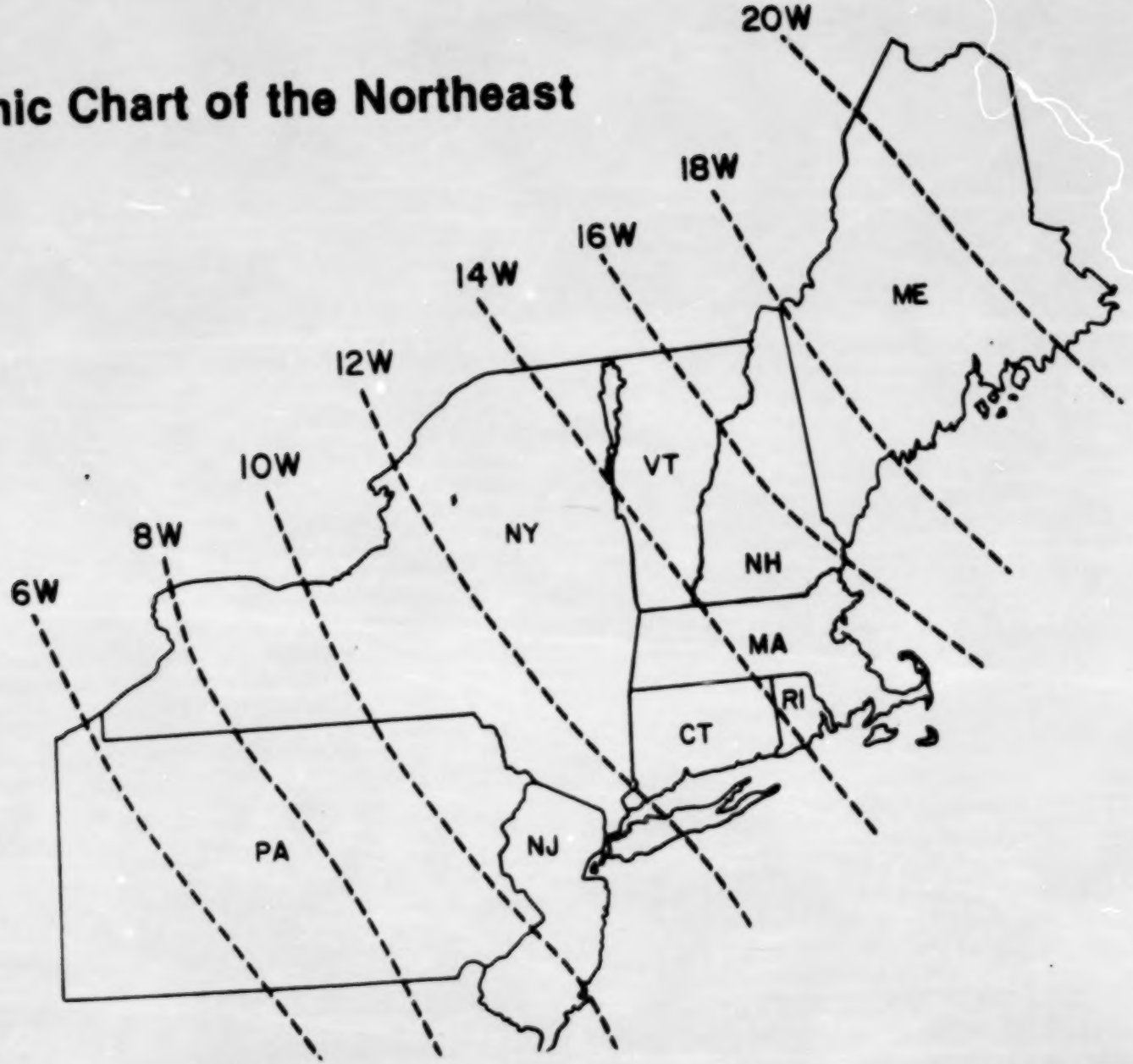


FIGURE 1.8 STAKE AND SHADOW METHOD

H-110

Isogonic Chart of the Northeast



- 26 -

There is an even faster way to determine your local north-south line. The shadow of a stake cast by the sun at solar noon will be on the true north-south line. Solar noon is exactly halfway between sunrise and sunset on any given day. Most local TV weather shows and newspapers give the exact times of sunrise and sunset each day.

Although performance will not be substantially affected, take local weather conditions into consideration when deciding on collector orientation. Although angling the collectors toward the east will start the system earlier in the morning, orientation slightly to the west can increase system performance because ambient temperatures are usually higher in the afternoon. As a result, collectors will lose less heat and operate more efficiently. If early morning fogs are common in your area, angle the collectors slightly toward the west.

COLLECTOR TILT

Collector tilt - the angle the surface of the collector makes with the horizon - is also an important factor in system performance. Ideally, collectors should be nearly as perpendicular to the sun's hottest rays as possible (Figure 1.9). For a solar DHW system, a tilt equal to the local north latitude is usually considered the optimum angle. Variations 10° either way will not

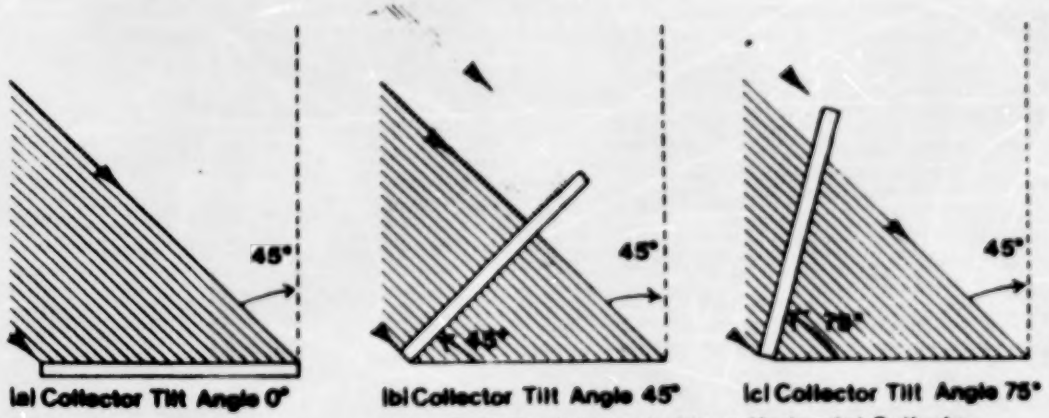


FIGURE 1.9: RADIATION ON HORIZONTAL, NORMAL AND NEARLY VERTICAL SURFACES

seriously affect the total annual performance of the system, all other things being equal, but a greater tilt will favor winter system operations when the sun is low in the sky (Figure 1.10). Also, in heavy snow areas a tilt of 50° will allow snow to slide off the collectors more readily. The following chart will help you determine the angle of the existing roof: (ANGLE/ROOF PITCH CONVERSION TABLE)

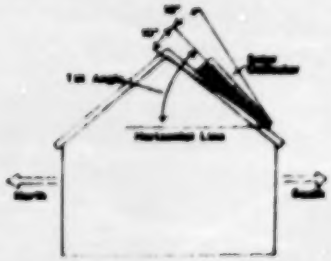


FIGURE 1.10: COLLECTOR TILT

TABLE 1.1 ANGLE/ROOF PITCH CONVERSION TABLE

SLOPE	PITCH	ROOF ANGLE (APPROX.)
2/12	1/12	9^0
3/12	1/8	14^0
4/12	1/6	18^0
5/12	5/24	22^0
6/12	1/4	26^0
7/12	7/24	30^0
8/12	1/3	33^0
9/12	3/8	37^0
10/12	5/12	39^0
11/12	11/24	42^0
12/12	1/2	45^0
13/12	13/24	48^0
14/12	7/12	50^0
15/12	5/8	52^0
16/12	2/3	54^0
17/12	17/24	55^0
18/12	3/4	57^0
19/12	19/24	59^0
20/12	5/6	60^0

COLLECTOR SHADING

No more than 5% of the collector area should be shaded between 9:00 a.m. and 3:00 p.m. Standard Time when greatest solar potential occurs. One of the major sources of shading is trees, so the home owner should be aware of the effect of future growth. Chimneys, dormers, other buildings, new construction, and even fences may shade the collector array, especially in the winter when sun angles are low and shadows are long. By knowing the altitude, (angle of sun above horizon) and azimuth (angle between true south and point on horizon below sun) of the sun throughtout the year, you can accurately determine if the homeowner is going to have shading problems.

THE SOLAR WINDOW

Imagine the sky as a transparent dome with its center at the solar collector array of a house. The path of the sun during the year can be etched (projected) on the dome, as can the outline of surrounding houses and trees (Figure 1.11). The sun's path during the optimum hours between 9:00 a.m. and 3:00 p.m. Standard Time throughout the year scribes a "solar window" on the dome. Almost all of the useful sunlight that reaches the collector array must come through this window, except for the amount resulting from diffuse radiation. If any surrounding houses, trees, hills, etc. block part of this window, that intrusion will cast a shadow on the collector. The elevation of the solar window in the local sky will decrease with increasing latitude.

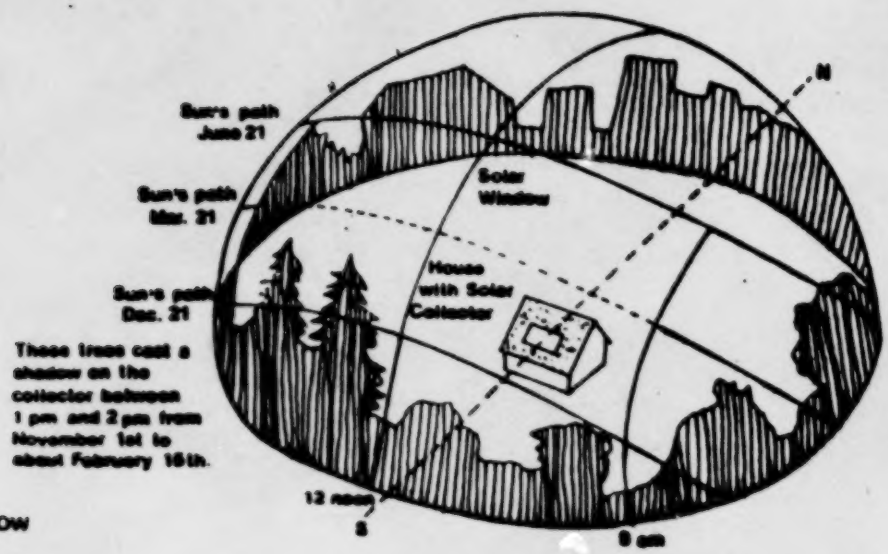

Sun's path June 21
Sun's path Mar. 21
Sun's path Dec. 21
Solar Window
House with Solar Collector
These trees cast a shadow on the collector between 1 pm and 2 pm from November 1st to about February 15th.
N
12 noon
8
8 am

FIGURE 1.11. THE SOLAR WINDOW

Mercator Projection

The sky dome with its "solar window" can be mapped using a Mercator projection in which the latitude and longitude lines are straight (Figure 1.12). Such a map is very useful for comparing the site surroundings with the "solar window", because

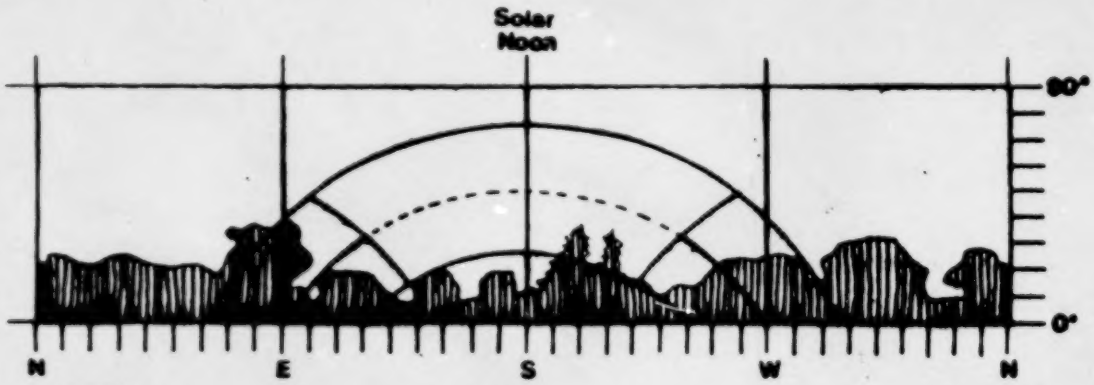


FIGURE 1.12 MERCATOR PROJECTION

both can be easily plotted on the map. Any elements surrounding the site that intrude into the "solar window" will cast shadows on the collector.

THE POPULAR SCIENCE SUN LOCATOR

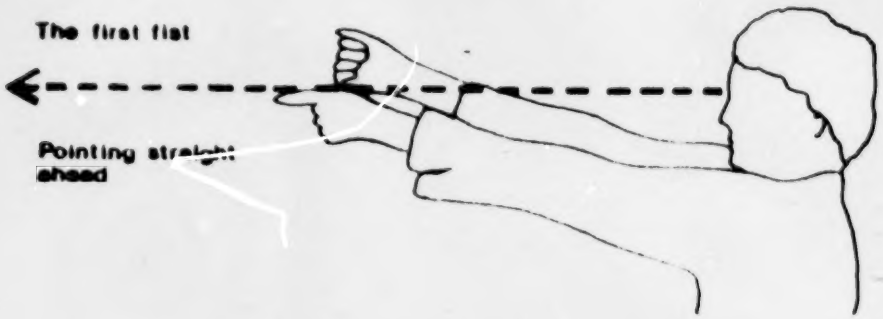
A simpler method was created for Popular Science Magazine*. Make a copy of the sun locator (Figure 1.13) and glue it to a cardboard backing. Trim along the line of the latitude nearest you. Place locator in a level position in the area where collectors are to be mounted. Align the compass along the correct magnetic declination line or per a recent isogonic chart (Figure 1.7) to obtain a true

north-south line (see Collector Orientation). Sight from the corner over the top of the latitude line from 9:00 a.m. to 3:00 p.m. This is the path the sun will take in midwinter. If more than 5 percent of the path is blocked, the site may need closer evaluation.

Even tree branches without leaves can block a considerable amount of winter sunlight if the branches are thick. Consider trimming, if necessary.

THE ENERGY TASK FORCE ROUGH APPROXIMATION METHOD

The Energy Task Force of New York suggests a way of roughly determining the solar window. Stand where the collectors are to be placed and face true south. Point so that your finger and your eye are horizontal (Figure 1.14). Place one fist on top of another the exact number of times to be determined by consulting the table (Table 1.2).



Sight over top of fists at true south and 30° east and west (with adjustments in fist height) to determine shading effects. Any object above your fists will cast a shadow on the collectors; and anything below your fists will be of no concern.

TABLE 1.2 THE ENERGY TASK FORCE SOLAR WINDOW APPROXIMATION METHOD

Latitude	12 o'clock position = 0° bearing	11 o'clock position = 30° bearing angle (EAST)	1 o'clock position = 30° bearing angle (WEST)
28°N	4½ fists (47° alt.)	3 fists (30° alt.)	same as 11 o'clock
32°N	3½ fists (34° alt.)	2½ fists (26° alt.)	same as 11 o'clock
36°N	3 fists (30° alt.)	2¼ fists (23° alt.)	same as 11 o'clock
40°N	2½ fists (27° alt.)	2 fists (20° alt.)	same as 11 o'clock
44°N	2¼ fists (23° alt.)	1½ fists (17° alt.)	same as 11 o'clock
48°N	2 fists (20° alt.)	1½ fists (14° alt.)	same as 11 o'clock

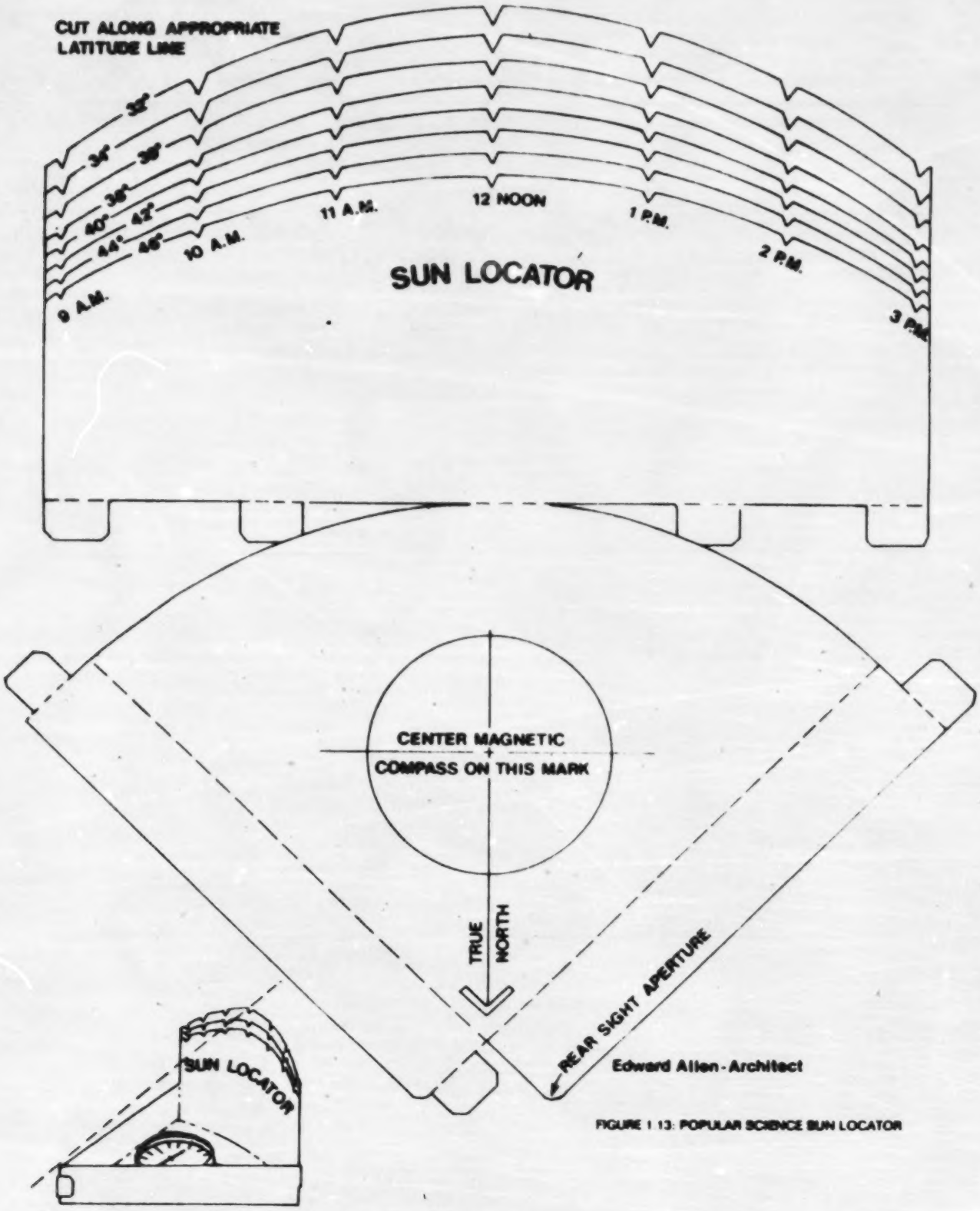
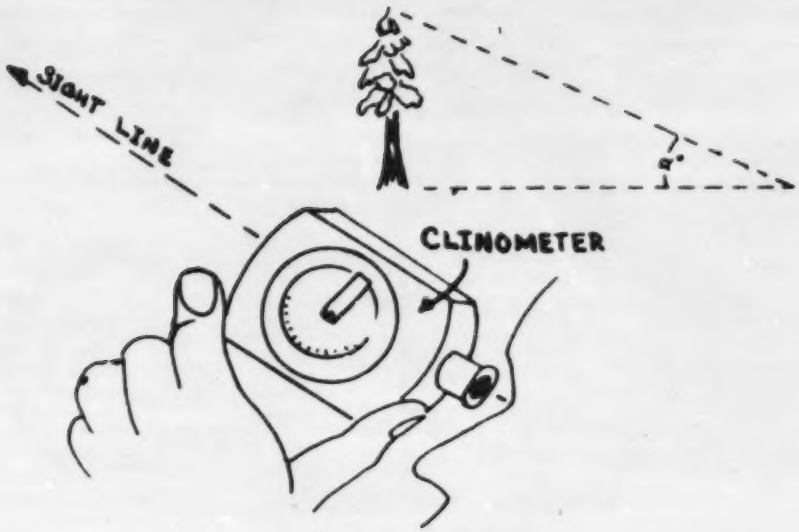


FIGURE 1 13: POPULAR SCIENCE SUN LOCATOR



CLINOMETER

A clinometer is a simple instrument used to measure vertical angles. This device may be used to determine roof angles by sighting up the slope of the roof.

The clinometer will also allow you to sight on the various features of the horizon especially those obstructing the winter sun. The altitude (vertical angle) and azimuth (compass bearing corrected for declination) of the obstructions and horizon features can then be plotted on a mercator grid. From this a plan for sight improvement can be formulated.

Procedure:

1. Construct a sun locator. Be sure to cut along the proper latitude line.

2. Choose a site for a solar-installation around your school.

3. Locate a true north-south line for this location using stake and shadow method, or compass with declination.

4. Starting with east (90^{o}) find the vertical angle (above 0^{o}) of trees, buildings, and uneven terrain in relation to your site using a clinometer.

5. Repeat Step 4 for each 10^{o} on the compass to south (180^{o}) and finally to west (270^{o}) and plot all points on your mercator grid.

6. Plot on your mercator grid the coordinates at each bearing. (Note whether trees are deciduous or coniferous as they will affect sunlight penetration at different times of the year).

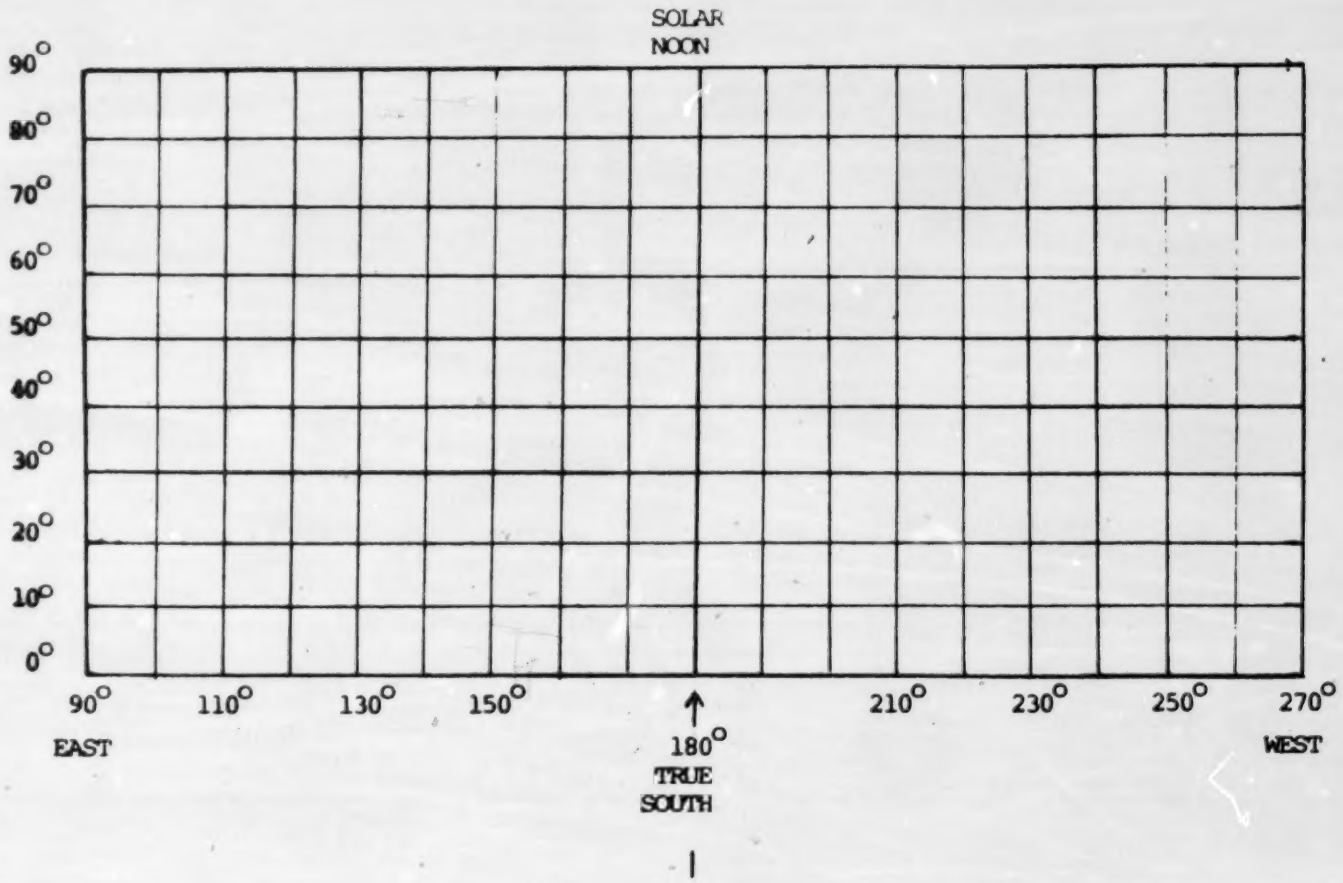
7. Determine if objects (trees, buildings, etc) are permanent or movable for later site modifications.

8. Using your "sun locator" determine the path of the midwinter sun across the sky for your site.

9. Plot this line on your mercator grid and determine what site features interfere with the sun's midwinter path.

10. Make a plan to modify the site for the best solar installation.

MERCATOR GRID



9/8/82

Dear Principal:

Last year you cooperated with us in the dissemination of our MODEL SOLAR TRAINING PROGRAM. The course was very successful in all aspects. The Bureau of Vocational Program Planning and Development, Connecticut State Department of Education, has once again funded this effort to help in the education of teachers in the area of Solar Energy.

We would appreciate your help in distributing the enclosed announcement to members of your staff who would find this program valuable. We are particularly interested in enrolling female teachers, including those in allied areas such as architecture, engineering and physics.

Since our current funding announcement was made considerably later than last year's, we are operating within compressed turn-around times. Therefore, we appreciate anything you can do to expedite the distribution and response to the enclosed announcement.

Thank you.

Donald P. La Salle

Donald P. La Salle, Ph.D.
Director

TALCOTT MOUNTAIN SCIENCE CENTER FOR STUDENT INVOLVEMENT, INC.

AVON CONNECTICUT
06001
PHONE 677-8571

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September 15, 1980

We are pleased to inform you that you have been selected as an alternate in the Science Center's Solar Energy Training Program. Should any of those selected as participants decide not to accept a place in the course, you would be able to fill the vacancy, should you desire to do so.

As you know, the program consists of a two-semester course taught at Talcott Mountain Science Center by Dr. Peter Lunde, who will be assisted by members of the Center's staff. The fall classes will be held on Tuesdays from 3:30 to 5:30 p.m., beginning on September 30th and will continue until December 30, 1980.

Please let us know if you wish to be considered as an alternate by filling out and returning the enclosed form.

Once again, congratulations on being selected as an alternate in a very competitive program. If you do not get an opportunity to participate in this year's program, please be advised that a similar program will be offered again in the fall of 1981.

Sincerely,

Donald P. La Salle, Ph.D.
Director

...OPERATION COMES ENTIRELY FROM FEES FOR SERVICES TUITIONS GRANTS AND GIFTS

TALCOTT MOUNTAIN SCIENCE CENTER FOR STUDENT INVOLVEMENT, INC.

AVON CONNECTICUT

ATTENTION: ALL TEACHERS AND ADMINISTRATORS OF VOCATIONAL AND TECHNICAL EDUCATION: (SHOP AND SCIENCE TEACHERS)

A MODEL SOLAR ENERGY TRAINING PROGRAM FOR VOCATIONAL EDUCATION TEACHERS

Talcott Mountain Science Center is pleased to announce that we are conducting, for a SECOND year, a program under contract with the Connecticut State Department of Education, Division of Vocational Education, Bureau of Vocational Program Planning and Development. This academic year offering is a MODEL SOLAR ENERGY TRAINING PROGRAM designed to teach fundamental engineering concepts involved in sizing and installing solar hot water systems. In addition, you will have the opportunity to install two such systems. Further, materials and laboratory activities suitable for use with your students will be included in the course of study.

For those participants interested in obtaining University credit for their involvement, arrangements can be made to accommodate them.

There is NO CHARGE for this exciting course, with the exception of those individuals enrolling for University credit.

The course will be conducted at the Science Center in Avon, for approximately half of the sessions, while the remaining class meetings will be held in two vocational technical schools located in geographically appropriate towns.

Since interest in this program is high (we had five applications for every place in the program last year) and the time line is short, we encourage you to complete and mail the Registration form below as soon as possible. Class meetings are planned for Tuesdays, 3:00 to 5:00 p.m. We would expect to start the program on September 23, 1980. The number of openings are limited to 25, so a rapid response is beneficial.

Registration
MODEL SOLAR ENERGY TRAINING PROGRAM FOR VOCATIONAL EDUCATION TEACHERS
FALL 1980

Name_____ School_____

Home Address_____
street city state zip

Phone_____
home business

Subject and Grade Level Presently Teaching:_____

___ I am interested in enrolling
___ I definitely plan to enroll
___ I wish to take the course for credit by the University of Hartford School of Engineering

Do you need directions to Avon?_____

TALCOTT MOUNTAIN SCIENCE CENTER FOR STUDENT INVOLVEMENT, INC.

AVON CONNECTICUT 06001

PHONE 677-8571

DONALD P. LA SALLE, Ph. D., Director
GEORGE C. ATAMIAN, Associate Director
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ARLES F. STRICKLAND, JR.
OBERT PANOSCIO, Ph. D.

September 15, 1980

Thank you for your interest in the Model Solar Energy Training Program for Vocational Education teachers. Unfortunately, because of limited enrollment in this pilot course, not all applicants could be selected.

We will be offering a similar course in the 1980-81 academic year and hope that you will consider enrolling at that time.

Please feel free to visit our appropriate technology resource center during the school year.

Sincerely,

Donald P. La Salle, Ph.D.
Director

Rejection letter

SERVICES TUITIONS GRANTS AND GIFTS

APPENDIX D

TALCOTT MOUNTAIN SCIENCE CENTER FOR STUDENT INVOLVEMENT, INC.

AVON CONNECTICUT
06001
PHONE 677-8571

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ROBERT ROBOTHAM
IAN ROY
CARLOS F. STACKBELL, Ph. D., M. D.
ROBERT PANDISCIO, Ph. D.

September 15, 1980

We are pleased to inform you that you have been accepted as a participant in the Solar Training Program. The program consists of a two-semester course taught at Talcott Mountain Science Center by Dr. Peter Lunde who will be assisted by members of the Center's staff. The fall class will be held on Tuesdays from 3:30 - 5:30 p.m. beginning September 30th and will continue until December 30, 1980.

Since enrollment in this course is limited, the competition for selection is keen. If you cannot attend, please let us know immediately so that we may contact the alternates.

Once again, congratulations on your acceptance. Please fill out the enclosed form and return to the Science Cetner promptly. Thank you.

Sincerely,

Donald P. La Salle, Ph.D.
Director

DPL/kf
Letter of Acceptance

... SERVICES, TUITIONS, GRANTS AND GIFTS

APPENDIX E

PARTICIPANTS

NAME	SCHOOL	TOWN
Bevis, Stuart	Portland J.H.S.	Portland
Billings, Bruce	Avon Old Farms	Avon
Boyle, Lawrence	Oliver Wolcott R.V.T.S.	Torrington
Britland, Edmund	Oliver Wolcott R.V.T.S.	Torrington
Burns, Gregory	Simsbury H.S.	Simsbury
Coffman, Douglas	Oliver Wolcott R.V.T.S.	Torrington
Cooper, Alice	Choate School	Wallingford
DiChristofaro, Ezio	Kennedy J.H.S.	Southington
Fairchild, Dick	Hartford Public H.S.	Hartford
Gillman, Thomas	Shepaug Valley	Washington
Harper, Wally	Hartford Public H.S.	Hartford
Ingellis, Patrick	Xavier High School	Middletown
Jones, Stewart	Torrington H.S.	Torrington
Konefal, Charles	Wilcox R.V.T.S.	Meriden
Muller, Kenneth	Torrington H.S.	Torrington
O'Neil, Barbara	Eastern J.H.S.	Greenwich
Panker, Rachel	Hamden High School	Hamden
Rodrigues, Peter	C. C. S. C.	New Britain
Rodrigues, Roy	Amity Reg. H.S.	Woodbridge
Rosolowski, Florence	Conrad High School	West Hartford
Schack, Lenore	Berlin High School	Berlin
Serbin, John	Hartford Public H.S.	Hartford
Skerker, Art	Hartford Public H.S.	Hartford
White, Craig	Simsbury H.S.	Simsbury
Ziegra, Albert	Institute of Living	Hartford

APPENDIX E

SCHOOL PARTICIPANTS FROM 1979-80 / 1980-81

Suffield High School	Suffield, Ct. 06078
Regional High School #17	Higganum, Ct. 06441
Oliver Wolcott Regional Voc. Tech.	Torrington, Ct. 06790
Howell Cheney Regional Voc. Tech.	Manchester, Ct. 06040
Bristol Central High School	Bristol, Ct. 06010
Somers High School	Somers, Ct. 06071
Wamogo Regional High School	Litchfield, Ct. 06759
American School for the Deaf	West Hartford, Ct. 06107
A. I. Prince Satellite	Simsbury, Ct. 06070
Simsbury High School	Simsbury, Ct. 06070
Greenwich High School	Greenwich, Ct. 06830
Enrico Fermi High School	Enfield, Ct. 06082
Norwich Regional Voc. Tech.	Norwich, Ct. 06360
H. C. Wilcox Regional Voc. Tech.	Meriden, Ct. 06450
Avon Old Farms School	Avon, Ct. 06001
Shepaug Valley High School	Bantam, Ct. 06750
Choate Rosemary Hall	Wallingford, Ct. 06492
Amity Regional Sr. High School	Woodbridge, Ct. 06525
Conard High School	West Hartford, Ct. 06107
Torrington High School	Torrington, Ct. 06790
J. F. Kennedy Jr. High School	Plantsville, Ct. 06479
Portland High School	Portland, Ct. 06480
Xavier High School	Middletown, Ct. 06457
Berlin High School	Berlin, Ct. 06037
Hartford Public High School	Hartford, Ct. 06105
Central Connecticut State College	New Britain, Ct. 06050

APPENDIX F

RESUME

PHILIP J. FINE

REGISTRATION — Professional Engineer - Connecticut

EXPERIENCE

July 1979 - Present

Principal
Energy Research Group, Inc.
Canton, Connecticut

Projects Include:

Energy Conservation - Survey of industrial, commercial and institutional buildings and equipment with complete audit of energy use. Identification of Energy Conservation Measures with economic analysis. Detailed analysis of industrial processes to minimize energy content of each product item.

Typical energy studies include:

- Three factories in Ohio for Edmont Wilson
- Becton Dickinson research center in Raliegh, N.C.
- Becton Dickinson pharmaceutical factory in Toronto, Canada.
- Geer Memorial Hospital, Canaan, CT.
- Millbrook Schools, N.Y.
- St. George's Church, Guilford, CT.
- Old Lyme Country Club.

Theoretical Research - Investigation and determination of the economic and performance benefits of standardizing solar energy components and system designs for commercial and industrial applications.

Development of a computer program to predict performance of a solar collector absorber plate of any shape, size and material to permit optimization studies.

ERG

APPENDIX F

VITA

Robert Smith Amrein

Present Position: Assistant Director, Special Programs Coordinator, Science Educator and Staff Geologist, Talcott Mountain Science Center for Student Involvement, Avon, Connecticut

Education:

Ph.D. Candidate, Boston College, Science Education
M.S., Boston College, Geophysics (1972)
B.A., Ricker College, Mathematics and Geology (1969)

Experience:

- Staff geologist and science educator (TMSC) 1973 to present
- Science Coordinator - Towpath School, Avon, Connecticut 1975 to present
- Adjunct Faculty member, University of Hartford, 1973 to present
- Special Programs Coordinator (TMSC)
- Solar Energy Resource Agent for New England Solar Energy Resource Center
- Metric Workshop Leader for State of Connecticut (1974-75)
- Teaching Assistant, Boston College Department of Geology, 1969 to 1972
- Teaching Assistant, Boston College Department of Education, 1972 to 1973.

Professional Organizations:

Sigma Xi

National Science Teachers Association

National Association of Geology Teachers

March 1978 - July 1979

Manager of Technical & Design Services
Sunworks Division of Enthone, Inc.
West Haven, Connecticut

Duties Include: In charge of four to six person engineering department.

Projects Include:

- Technical assistance to approximately fifty manufacturers' representatives throughout the United States and Canada.
- Technical assistance to consulting engineers, plant engineers and building owners regarding feasibility and design of solar energy systems.
- Representative for field service to assist in correction of collector and system problems.
- Product modification and improvement.
- Development of new liquid and air collector designs including selection of alternative materials and fabrication techniques to reduce material and manufacturing costs.
- Construction of prototypes to experiment with manufacturing techniques and to conduct thermal performance tests.
- Development of computer programs to simulate system performance and perform economic analysis.
- Comparative testing of various types of solar domestic hot water systems.
- Conducted investigation into system fluid contamination probelms.
- Assisted manufacturing personnel in solving fabrication problems and establishment of quality control criteria.
- Exhibitor at various industry trade shows (SEIA, ASHRAE) including Department of Commerce technology show in Europe.

Alternate Energy - Evaluation of industrial solar energy applications by surveying plant buildings and processes to identify where solar energy could be effectively used followed by determination of economic feasibility and system design.

Conceptual and economic evaluation of industrial, commercial and residential solar energy systems.

Design of Energy Effective Buildings - Museum of Artifacts and tourist information center for the Mojave Desert. The theme is to make the building energy self-sufficient and make use of the optimum combination of passive and active solar energy.

- Office building in Avon, CT.
- HUD passive solar project, Canton Connecticut.
- Various single and multi-family residences.
- Energy effective greenhouses, Lebanon, CT.

Jan. 1974 - Oct. 1977

Dubin Bloome Associates
Consulting Engineers
West Hartford, CT

Duties Include: Design/product engineer in heating, ventilating and air conditioning department. Particular emphasis on energy conservation as related to the design and operation of heating and air conditioning systems and the design of solar energy systems. for heating, hot water and air conditioning.

Project Include:

- Technical evaluator/reviewer for the HUD Residential Solar Energy Demonstration Program. Tasks in this program included:

  a) Member of the technical review panel evaluating the technical feasibility of grant applications.

  b) One of two technical advisors to the Grant Application Review Panel which made final selection of applicants.

  c) Review of final drawings and specifications for projects receiving grants.

- Project engineer for a study of solar assisted heat pumps conducted for the USAF. The study was divided into three phases beginning with identification of various solar/heat pump combinations and concluding with final design and installation of the selected system in a housing unit at Little Rock AFB. Potential energy conservation measures were also investigated.

- Project engineer for an energy conservation study for four buildings at Argonne National Laboratory, Argonne, IL. Conducted field inspections of buildings and mechanical systems to determine areas of potential energy savings. Prepared report identifying and evaluating energy conservation measures recommended for implementation.

- Project engineer for a solar energy feasibility study for an elderly housing project in Detroit Lakes, MN. Project involved a site investigation to determine potential uses for solar energy and preparation of a report identifying the various alternatives available with an economic analysis to determine the most favorable alternative.

Oct. 1977 - March 1978	Project Engineer NPD Energy Systems, Inc. (Subsidiary of National Patent Development Corp.) Cambridge, MA & Farmington, CT.
Duties Include:	Project engineer in charge of development of prototype photovoltaic/thermal tracking solar energy module. Supervised activities of seven persons involved in this project in Cambridge, MA. Coordinated and expedited manufacture and shipment of special components supplied by various vendors. Provided design input for system aspects of project. Terminated employment with NPD Energy Systems upon relocation of company to Rockville, MD.

Projects Include: (cont'd)

- Assisted with preparation of a Conceptual Design Report for the NASA Flight Center, Edwards Air Force Base, Edwards, CA. Project consisted of retrofitting an existing building with a solar energy system consisting of approximately 20,000 square feet of collectors used for heating, cooling and hot water.

- Design development of the solar energy and automatic control systems for the Towns Elementary School in Atlanta, GA. The system included 10,000 square feet of solar collectors used for heating, cooling and hot water. The system has been operating since early 1976.

- Design development of the solar energy and automatic control systems for the Administration and Research Building of the Cary Arboretum in Millbrook, N.Y. This project includes 5,000 square feet of solar collectors used for heating and hot water. The automatic control system selects various heating and cooling modes and operates the solar energy system with the objective of minimizing energy consumption. The building has been occupied since early 1978.

Projects Include: (cont'd)

- Project engineer for an energy conservation and solar energy feasibility study for an apartment building owned by the Housing and Redevelopment Authority of Mankato, MN. Project involved a site investigation to determine potential areas for energy conservation and uses of solar energy. Results were summarized in a report identifying the energy conservation measures studied and the alternative uses of solar energy. Final recommendations were based on an economic analysis of the alternatives.

- Project engineer for two residential solar energy installations. Both projects emphasized energy conservation and included design of solar energy systems for heating and hot water.

- Design engineer for preparation of a report on energy conservation opportunities and guidelines for existing retail, office and religious buildings prepared for the Federal Energy Administration. The report was prepared in two volumes to divide energy conservation measures into low (less than $1000) and high capital expenditures. Assisted in the development of approximately seventy-five figures to allow graphical determination of energy savings resulting from various types of energy conservation measures.

- Design engineer for an energy conservation study at Kings Point Merchant Academy. Involvement included site visits and inspection of steam distribution and control systems and analysis of energy savings for approximately twenty measures recommended for implementation.

- Design team member for a Conceptual Design Report for Program Support Facility and Environmental Evaluation Laboratory for Argonne National Laboratory, Argonne, IL. Scope included extensive analysis of energy conservation and a solar system for heating, cooling, domestic hot water and process loads.

A Model Solar Energy Training Program
for
Vocational Education Teachers
1980-1981

* * * * *

Sept. 30 - Introduction - Dr. La Salle, Director of TMSC
What the course involves
Tour of Talcott Mountain Science Center
Looking at the problem: Where & How to Mount the Solar Heating System.
- Robert Amrein, Assistant Director, TMSC;
- Ed Morris, H. C. Wilcox Reg. Voc. Tech School owner of A-1 Solar Co.

Oct. 7 - Roof Mount - Construction and Mounting
Ed Morris, H.C. Wilcox Tech./Robert Amrein, Asst. Dir.

Oct. 14 - Continued work on roof mounting
Ed Morris, H.C. Wilcox Tech./Robert Amrein, Asst. Dir.

Oct. 21 - Collector Construction: explanation of each part and what it serves.
Dr. Lunde, Consultant for Hartford Graduate Center
Ed Morris, H.C. Wilcox Tech.

Oct. 28 - Lecture on Radiation - Bill Danielson, Sr. Assistant Director of TMSC

Nov. 4 - Start of actual construction of collectors
- Ed Morris, H.C. Wilcox Tech.
- Robert Amrein, Assistant Director

Nov. 18 - Solar Energy for the Homeowner; actual on-site visit
- Ed Butler, Sunrise Solar Service
- George Atamian, Associate Director of TMSC

Nov. 25 - Lecture: Collector Location and Orientation
- Mr. Phil Fine, Vice President, Energy Resource Group

Dec. 2 - Finish Construction of Collector Panels
- Ed Morris, H.C. Wilcox Tech.
- Robert Amrein, Assistant Director

Dec. 9 - Roof Mounting of Panels
- Ed Morris, H.C. Wilcox Tech./Robert Amrein, Asst. Dir.

1970-1974	Morton S. Fine & Associates, Inc. Consulting Engineers Bloomfield, CT
Duties Include:	Responsibilities included surveying computations and field work and design experience in traffic engineering, storm and sanitary sewers, and sanitary sewer pumping stations.
1966-1970	Officer, United States Navy
Duties Include:	Served as Engineering Officer on destroyer type reserve training ship and on staff of Landing Ship Squadron Nine. Responsible for training of Engineering Department Personnel and maintenance of ship's main propulsion and auxiliary equipment. Installed and administered preventative maintenance programs on eight LST's. Received spot promotion to Lieutenant Senior Grade.
Awards:	Meritorious Unit Commendation Vietnam Service Medal National Defense Service Medal

EDUCATION

1960-1963	Worcester Polytechnic Institute Major in Civil Engineering
1963-1966	University of Hartford Major in Psychology - BA 1966
1970-1973	University of Hartford Major in Mechanical Engineering - BSME 1973
1975-1978	University of Connecticut Major in Business Administration - MBA 1978

APPENDIX G

Dec. 16 - Roof penetration for piping to storage
- Ed Morris, H.C. Wilcox Tech./Robert Amrein, Asst. Dir.

Jan. 6 - Array piping configuration lecture - flow rate
- balancing
- expansion

Jan. 13 - Hot Air and other activities - Jonathan Craig, TMSC staff

Jan. 20 - Heat Transfer Fluids and Types of Systems
- Phil Fine, Vice President, Energy Resource Group

Jan. 27 - System Sizing I - Phil Fine, Vice Pres., Energy Resource Group

Feb. 3 - System Sizing II - Phil Fine, V.P., Energy Resource Group

Feb. 10 - Thermatool Trip - Phil Fine, V.P., Energy Resource Group

Feb. 24 - Common Errors - Phil Fine, V.P., Energy Resource Group

Mar. 3 - Return to installation of hot water and space heating
- Ed Morris, H.C. Wilcox Tech.
- Ed Butler, Sunrise Solar Service
- Robert Amrein, Assistant Director

Mar. 10 - Heat Pumps - Dr. Ed Kush, Brookhaven Labs

Mar. 17 - Computer use for system sizing, Phil Fine, V.P., Energy Resource Group

Mar. 24 - Computer use for system sizing, Phil Fine, V.P., Energy Resource Group

Mar. 31 - Installation of Hot H_2O

Apr. 7 - " " " "

Apr. 14 - " " " "

Apr. 21 - " " " "

Apr. 28 - " " " "

May 5 - " " " "

May 12 - " " " "

May 19 - " " " "

May 26 - " " " "